COMMONWEALTH OF AUSTRALIA

Council for Scientific and Industrial Research

A Guide to the Seasoning of Australian Timbers

Part I

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By

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FOREWORD.

As a result of the constantly increasing interest in kiln-seasoning, the Division receives so many requests for drying-schedules for specific Australian timbers that it has been decided to publish, in a collected form, such information in this regard as is available.

At the present stage, this information does not by any means cover the complete field of Australian commercial timbers. Neither is it claimed that the recommendations made herein may not be subject to slight modification in the light of further experience. But all the observations and recommendations included are the result of careful investigation, and can be adopted with confidence of success. Any modifications that might eventually be found desirable are likely to be in the nature of refinements rather than of alterations.

This Pamphlet is the first of a series, later numbers of which will be issued from time to time as additional information is gathered, both with regard to those timbers dealt with now and to other species. The ultimate object is to develop schedules for all the principal Australian timbers, both quarter-sawn and back-sawn, in all the commonly used dimensions. In this first part, two exotic species grown locally and likely to become of increasing importance, have been included.

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June, 1933.

SUMMARY.

Timbers of different species differ so widely in physical properties that it is impossible to prescribe a general set of conditions for air or kiln drying for all timbers. For this reason, the drying of mixed kiln charges can never be really satisfactory.

Even within the one species, there is sometimes a decided difference in drying characteristics necessitating the sorting of the material and the use of different drying schedules if completely satisfactory seasoning is to be obtained.

The kiln drying of a number of Australian timbers has been investigated in small laboratory kilns. Tests of some of the schedules thus developed have also been made in large commercial kilns. In addition, for a few timbers, the Western Australian Forests Department has kindly given permission for schedules to be included.

Based on the results of the work mentioned above, suggested drying schedules for seventeen timbers, including two exotic timbers grown in Australia, namely, insignis or Monterey pine and willow, are given. It is important to note that the conditions given in the schedule apply to the air just before it enters the stack.

In the later portions of the report, under "Supplementary Notes," various factors of importance in practical seasoning, namely, the moisture content, shrinkage, stresses and set, checking, warping, collapse, and kiln schedules are discussed.

A Guide to the Seasoning of Australian Timbers.

PART I.

Notes on Seasoning Characteristics of, and Suggested Kiln Schedules for, 17 Species, with Supplementary Notes on Drying, Drying Stresses, and Degrade.

I. INTRODUCTION.

The conditions most suitable for drying any particular timber are dependent on the physical properties of that timber, such properties influencing both the rate of drying under a given set of conditions and the tendency towards degrade during drying.

Because of this fact and because timbers of different species differ so widely in physical properties, it is impossible to prescribe a general set of conditions for drying all timbers, and although in some cases timbers with similar properties can be dried under the same conditions without fear of degrade, there are very few instances in which such timbers will dry at the same rate. For this reason, the kiln-drying of charges of mixed species can never be really satisfactory. The best that can be hoped for under such procedure is to delay the drying of portion of the charge in order to prevent degrade in the remainder. In other words, where this undesirable practice cannot be avoided, the drying conditions must be fixed to suit the most refractory or slowest drying timber in the charge, and there will be a consequent waste of time in so far as the less refractory or quicker drying portion of the charge is concerned.

Even within the one species there is sometimes a decided difference in drying characteristics, necessitating the sorting of the material and the use of different schedules if completely satisfactory drying is to be obtained. A notable example of this is myrtle (*Nothofagus cunninghamii*). Moreover, different drying conditions are necessary for different thicknesses of the same timber, and for back-sawn and quarter-sawn material. For example, thin case material can be dried with excellent results under conditions that would be ruinous for thicker material. The reason for this is that thin pieces dry through to the centre before severe stresses can be set up, whereas in the thick material the outer portions dry much more rapidly than the inner, setting up stresses which in turn cause degrade of the stock.

The natural tendency is for back-sawn material of a given species to dry more rapidly than quarter-sawn material of the same species dried under the same schedule. But the back-sawn material also tends to degrade more seriously, and the rate of drying must be reduced to prevent this, so that frequently a longer time is required to dry back-sawn material and keep it free from degrade than to dry quarter-sawn material of the same species and dimensions. This difference in the drying characteristics of back-sawn and quarter-sawn material has a direct bearing on the drying problems in several of the States. For example, it is the practice in Western Australia to saw jarrah flooring on the back. The kiln-drying of jarrah flooring

therefore requires greater care than if this were not the case. In Victoria and Tasmania, on the other hand, *Eucalyptus regnans* flooring is now usually quarter-sawn, with the result that the drying problem is simplified very considerably, with consequent reduction in costs. When a charge consists of a mixture of back-sawn and quarter-sawn stock, the drying schedule must be chosen to suit the back-sawn material.

Considering a charge of timber of one species and of one thickness, it is inevitable that there should be some variation in direction of cutting with respect to growth rings, in initial moisture content, and possibly in some other property, such as density. Consequently, no schedule can be developed that will be ideal for every board in the charge. The most that can be done is to arrive at a set of conditions that will dry the charge in the least possible time with the least possible degrade, leaving no boards at too high a moisture content and over-drying none. It is worth mentioning in passing that a very common fault in present practice, due to imperfect kiln design or operation, is to over-dry a considerable portion of a charge in order to make sure that none of the charge is insufficiently dried. If a kiln is so faulty as to cause uneven drying in different parts of the charge, it is the operator's job to see that his conditions are so regulated that over-drying of any portion of the charge does not occur.

Some of the information included in this Pamphlet has been gathered from outside sources, and special acknowledgment is made to the Western Australian Forests Department for permission to reprint schedules for the three Western Australian timbers included, and to the Forests Commission of Victoria, from whose records information relative to some of the Victorian timbers has been obtained. Acknowledgment is also due to the Forest Products Laboratory of Madison, U.S.A., whose Kiln Drying Handbook has been referred to freely, and to H. D. Tiemann of the same laboratory, whose articles on seasoning stresses and allied subjects have been of considerable assistance.

So far as the notes and schedules for species are concerned, the preliminary investigations have, except in those cases cited, been made in small experimental kilns with which the Division has been working for the last three years, and three of which are now in constant operation. After schedules have been evolved in these laboratory kilns, they have, where possible, been tried out on a commercial scale. Experience has shown this procedure to be entirely satisfactory, and it makes possible the rapid development of schedules without risking the waste of large quantities of timber. The two main factors on which such small scale tests are dependent, to make them comparable with commercial runs, are adequate end-coating of the short boards used and selection of material. Where due regard is given to these two points, the only differences between the small scale tests and commercial runs are firstly, the time necessary to complete a run; secondly, possible slight modifications due to variations of properties that cannot be covered completely in small tests, even with the most careful selection; and thirdly, the fact that the degree of warping in short lengths is not a reliable indication of that which might occur in long lengths. The difference in drying time is due to the lag in drying caused by the width of the stack in a commercial kiln, this lag varying somewhat according to the design of commercial kiln used and being reduced to a minimum in modern high-speed kilns with reversible circulation.

Indication is given of those cases where commercial tests have not yet been made, but it is not likely that such schedules will need great modification as a result of subsequent commercial tests, or that the estimated drying times for efficient commercial kilns will be far out. Taking the schedules as a whole, they will, if applied in satisfactory kilns, ensure good results provided the timber in any charge is reasonably uniform in initial moisture content. Further, the time taken will be the least that is safe, so far as present knowledge can guide us. In one or two cases, higher temperatures and greater wet bulb depressions* than those recommended are being used in commercial plants. It is doubtful, however, if anything is gained by the use of such severe conditions, and there are definite disadvantages, even though they do not lead to apparent degrade.

It is important to note that the conditions given in these schedules apply to the air just before it enters the stack. As a further aid to kiln operators, the schedules are supplemented in each instance by notes on the general drying characteristics of the species. It is possible that minor modifications of the schedules may be made as further information is gathered, especially in the case of those timbers on which work done to date has been limited to the small experimental kilns.

It will be noted that considerable stress is laid on the practice of partially air-drying most hardwood stock prior to kiln-drying. Although a suitable kiln makes possible the kiln-drying of stock green off the saw, if necessary, this procedure requires considerably more care, and, with hardwoods, is in most instances more expensive than the combination of air-drying and kiln-drying. The Division strongly recommends the partial air-drying of hardwood timbers prior to kiln-drying, except where very thin stock, such as case material, is being dried, or where rapid drying can be obtained without fear of degrade, or where the stock tends to check badly during air-drying. In the last case, a skilful kiln operator with a suitable kiln can turn out a better product by kiln-drying from the green condition, although the cost of so doing may be relatively high.

It is necessary to realize that a kiln operator cannot expect to attain complete success by blindly following the schedules suggested here. He must understand the principles involved in drying timber, and, particularly when drying material green off the saw, must decide, on the behaviour of his charge, whether slight modifications or intermediate steaming or high humidity treatments are necessary. Some guidance in this regard is offered at the end of the Pamphlet, in the supplementary notes, which also contain definitions of some of the terms used throughout the text.

It is well to note here that any final steaming treatment (under saturated conditions) should be followed by a short period of re-drying. In warm dry weather, this re-drying can be carried out in the open air. In humid weather, it should be carried out in a kiln or in a slightly heated drying-off shed.

It should be noted, also, that timber which has been through a kiln or reconditioning chamber should not be machined until it is thoroughly cool.

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* *For description of wet bulb depression see supplementary notes.*

II. SPECIES DISCUSSED.

cacia melanoxylon—Blackwood (Tas., Vic., N.S.W.).

General Notes.

Some information is available regarding the drying of a few charges of 1-inch boards in commercial kilns, the indication being that this timber is easily dried without degrade, even in back-sawn boards. Such general observations have been supplemented by one laboratory kiln charge of narrow back-sawn boards, and while it cannot be claimed that further investigation is unnecessary, it is safe to record the following notes and suggestions. Comparatively large squares have been dried commercially, but no details of degrade occurring are available.

Warping.—Cupping of wide back-sawn boards is the most likely form of warping to be experienced, but if not prevented by the weight of the stock, can be removed by a final steaming treatment.

Checking.—Very little trouble is experienced from checking, even in back-sawn material.

Collapse.—No apparent collapse has been observed, but the possibility of increasing the final dry dimensions by a reconditioning treatment has not been investigated.

Shrinkage.—The only figures available relate to back-sawn boards kiln dried from the green condition to a moisture content of 12 per cent., the tangential shrinkage in these being about 5 per cent.

Suggested Schedule.

The following schedule is suggested from the results of one laboratory kiln test with 5-in. x 1-in. green, back-sawn boards, and it is probable that it would be satisfactory for wide back-sawn boards. A drying time of about seven days is estimated for commercial kilns. When further work has been done, it might be possible to reduce this time, and kiln-drying material from the green condition will probably be economical.

For the relief of stresses at the end of the drying schedule, a steaming treatment under saturated conditions at a temperature of about 170°–180° F. is suggested. About two hours of such treatment should be sufficient for 1-inch stock. If steaming under saturated conditions is found to cause checking in wide back-sawn material, a high humidity treatment should be substituted, holding a temperature of about 170°–180° F. with a wet bulb depression of about 8° F. Such a treatment would take considerably longer than steaming under saturated conditions.

TENTATIVE SCHEDULE FOR 1-INCH GREEN BACK-SAWN BLACKWOOD.

Change Points.	Dry Bulb Temperature.	Wet Bulb Depression.	Relative Humidity.
	° F.	° F.	%
Initial	140	10	75
40 % moisture content	150	15	66
30 % „ „	155	25	49
20 % „ „ (to final) ..	160	30	43

Atherosperma moschatum—Sassafras (Tas. and Vic.).

General Notes.

Information on the drying of this timber is limited to general observations made from time to time and to one laboratory kiln investigation of the combined air- and kiln-drying of a charge of 1-inch quarter-sawn stock. As the timber seems to be particularly easy to dry without degrade, however, such observations as have been made are recorded here as a guide to those wishing to dry it before further information is obtained.

Warping.—Very little warping, and none of a serious nature, has been observed, although one user reports that warping causes trouble at times.

Checking.—Neither in the air-drying of squares up to 3 in. x 3 in. nor in the kiln-drying, under a comparatively severe schedule, of partially air-dried 1-inch quarter-sawn stock, has any serious checking been noted.

Collapse.—No apparent collapse has been observed, but the possibility of increasing the dry dimensions by a reconditioning treatment has not been investigated.

Shrinkage.—Radial shrinkage only has been noted, the maximum figures obtained in drying to a moisture content of 12 per cent. being 4 per cent.

Suggested Schedule.

As previously pointed out, kiln-drying observations have been limited to partially air-dried 1-inch quarter-sawn material, and even then to a small quantity of material only. The following schedule should be quite safe for such material, however, and the drying time in a commercial kiln should not be more than five days.

A final treatment for the relief of stresses was not given in the case of the laboratory kiln charge dried, but it is probable that a steaming treatment under saturated conditions at a temperature of about 180° F. could be given without danger of checking. Such a treatment would probably need to last for about two hours, for 1-inch stock, and correspondingly longer for thicker stock. An alternative treatment would be a high humidity treatment, holding a temperature of 170°–180° F. with a wet bulb depression of about 8° F. A considerably longer time would be necessary for this treatment to be effective.

TENTATIVE SCHEDULE FOR 1-INCH PARTIALLY AIR-DRIED QUARTER SAWN ATHEROSPERMA MOSCHATUM.

Change Points.	Dry Bulb Temperature.	Wet Bulb Depression.	Relative Humidity.
	° F.	° F.	%
Initial (about 30 % moisture content) ..	150	18	60
20 % moisture content (to final)	160	30	43

When further work has been done, it will probably be shown that kiln-drying from the green condition can be carried out economically.

Dacrydium franklinii—Huon Pine (Tas.).

General Notes.

General observations indicate that this timber is very easy to dry without degrade, but systematic observations have been limited to one laboratory kiln test with 1-inch back-sawn material. The following notes and suggestions are not by any means final, but give a safe guide to the drying of this timber.

Warping and Checking.—No trouble from either of these sources of degrade is common.

Collapse.—Collapse has not been observed, except in small areas localized around places where borers have been active. Such areas as have been noted were discoloured, slightly softer than the surrounding timber, and obviously contained decay.

Shrinkage.—Shrinkage measurements have been confined to a few back-sawn boards, the tangential shrinkage of these, in drying to a moisture content of 12 per cent., being about 4 per cent.

Suggested Schedule.

The following schedule is based on the results of one laboratory kiln test made with green back-sawn boards, and is suggested tentatively for kiln-drying this timber until further information is obtained. Using this schedule, the time required to dry green 1-inch material in a commercial kiln would probably be about four or five days, and on this basis kiln drying from the green condition should be economically sound.

For the relief of stresses at the end of the drying schedule, it is suggested that a steaming treatment under saturated conditions at a temperature of 190°–200° F. be given. About half an hour to one hour of such a treatment should be sufficient for 1-inch stock. An alternative treatment would be a high humidity treatment, holding a temperature of 190°–200° F. with a wet bulb depression of 8° F. This treatment would require considerably longer than that of steaming under saturated conditions.

TENTATIVE SCHEDULE FOR 1-INCH GREEN BACK-SAWN HUON PINE.

Change Points.	Dry Bulb Temperature.	Wet Bulb Depression.	Relative Humidity.
	° F.	° F.	%
Initial	180	15	70
40 % moisture content	180	20	62
30 % ,, ,, (to final)	180	30	47

Endiandra palmerstoni—Queensland Walnut.

General Notes.

To date, the Division's observations on the drying of this timber have been limited to small experimental kiln runs with 1-inch boards of various widths. Back-sawn and quarter-sawn boards have been

dried, and tentative schedules developed for drying both green off the saw and after partial air-drying. These schedules have not yet been applied in commercial kilns.

Checking, Warping, and Collapse.—The experimental work indicates that the timber should not offer any difficulty in drying, even when sawn full on the back. The material used dried rapidly without any tendency towards either surface or internal checking, and so far as could be judged from short lengths, without serious tendency to warp. It showed a slight tendency to collapse, not resulting in marked unevenness of shrinkage, but being detected by a slight permanent gain in size after a final reconditioning treatment. In each run the moisture content of the cores of boards at the end of the drying period was higher than was desirable, and severe case compression stresses were present. Six hours' steaming under saturated conditions at 212° F., followed by a short period of re-drying, evened up the moisture distribution, left the boards practically free of stress, and resulted in a slight permanent gain in size.

There is some variation between these results and the reported behaviour of the timber in England, where it has been reported that Queensland walnut is very prone to split unless quarter-sawn. It is possible that such reports might be based on the behaviour of thick stock, which has not been investigated here as yet. On the other hand, long 1-inch boards might have a tendency to develop end splits during drying if the ends are not coated, and investigations in this regard are necessary.

Shrinkage.—Shrinkage data available indicate the maximum shrinkage to be expected, when drying to a moisture content of 12 per cent., to be 4 per cent. in a radial direction and 7 per cent. in a tangential direction.

Suggested Schedules.

The following tentative schedules for 1-inch stock are suggested, but they may be subject to slight modification after trial in commercial kilns, where a wider range of material might introduce variations in properties.

The drying time necessary for 1-inch stock in commercial kilns would be about ten to twelve days when drying green off the saw, and about four days for material previously air-dried to a moisture content of 30 per cent. In either case, it is suggested that the material be dried to a moisture content of about 10 per cent., then steamed for about six hours under saturated conditions at 212° F., and re-dried to the final moisture content required. The exact length of steaming treatment necessary in commercial kilns must be determined by experience, the objectives being removal of stresses, overcoming of slight collapse, and removal of warping if present.

Whether or not preliminary air-drying is more economical than kiln-drying from the green condition must be decided on the relative merits of each method in any particular instance, taking into consideration such factors as handling charges, space required, capital invested in air-drying stacks and in kilns, and uniformity of stock to be dried. Where kiln-drying green off the saw is desired, no difficulty from degrade should be experienced with this timber.

TENTATIVE SCHEDULE FOR 1-INCH GREEN QUEENSLAND WALNUT.

Change Points.	Quarter-sawn.			Back-sawn.		
	Dry Bulb Temperature.	Wet Bulb Depression.	Relative Humidity.	Dry Bulb Temperature.	Wet Bulb Depression.	Relative Humidity.
	° F.	° F.	%	° F.	° F.	%
Initial	160	9	79	160	9	79
50 % moisture content ..	160	19	60	160	16	65
40 % ,, ,, ..	170	34	40	170	27	49
20 % ,, ,, (to final)	180	45	30	170	43	30

TENTATIVE SCHEDULE FOR 1-INCH QUEENSLAND WALNUT AIR-DRIED TO MOISTURE CONTENT OF 30 PER CENT.

Change Points.	Quarter-sawn.			Back-sawn.		
	Dry Bulb Temperature.	Wet Bulb Depression.	Relative Humidity.	Dry Bulb Temperature.	Wet Bulb Depression.	Relative Humidity.
	° F.	° F.	%	° F.	° F.	%
Initial (about 30 %)	160	25	50	160	19	60
20 % moisture content (to final)	180	45	30	170	43	30

Eucalyptus diversicolor—Karri (W.A.).

General Notes.

The schedules suggested for this timber, apart from those for case stock, are included by courtesy of the Western Australian Forests Department, and are the result of considerable work in semi-commercial and commercial kilns in that State. The case stock schedules are suggested as a result of laboratory kiln investigations only, and have not been tried out in commercial kilns.

Warping.—Although this timber is, on the whole, much straighter in the grain than jarrah, considerable trouble from warping was experienced, at times, in the tests in connexion with case stock. These indicated that such warping is not permanently removed, nor even appreciably reduced, by a final steaming treatment. This warping was possibly due to the interlocked grain.

Checking.—Karri has a pronounced tendency to check during seasoning, and in thick pieces, under adverse conditions, the cracks become very deep. While the usual form of checking is across the growth rings, therefore appearing on the wide surface of back-sawn boards, there is also an appreciable tendency to form fine checks parallel to the growth rings, and these appear on the wide surface of quarter-sawn boards.

Collapse.—Collapse is somewhat more prevalent than in jarrah, but in neither timber is it comparable in severity with that occurring in the Eastern States' timbers of the *Eucalyptus regnans* type. Reconditioning is not recommended.

Shrinkage.—The only shrinkage figures available are for thin case stock, in which a tangential shrinkage of up to 10 per cent. and a radial shrinkage of up to 5 per cent. were observed, in drying to a moisture content of 15 per cent.

Suggested Schedules.

The pronounced tendency to check makes strict adherence to schedules essential in kiln-drying this timber from the green condition, and in air-drying or partial air-drying considerable care must be taken to prevent checking. When air-drying large sections in dry locations, in addition to using very thin spacing strips (about $\frac{1}{4}$ inch to $\frac{1}{2}$ inch thick), it is also frequently necessary to build sun shields and to slow down air movement through the stacks by closing the ends of flues between stacks.

Although schedules are given for kiln-drying green material, partial air-drying prior to kiln-drying is recommended, as it eliminates the need for extremely close control of kiln conditions. Care must be taken to prevent checking during the air-drying period.

Another difficulty encountered in drying this timber is the slow rate of transfusion of moisture from the centre of each piece to the surface, and periodical steaming treatments, under saturated conditions at a temperature about 10° higher than the drying temperature, are advised throughout the early part of the run, when kiln-drying from the green condition.

One-inch Stock.—Schedule I. is for back-sawn boards; quarter-sawn stock should be dried to a schedule 5° F. higher throughout, with the same relative humidity. The practice of quarter-sawing, which has proved of such great economical advantage with *Eucalyptus regnans* and similar species, is strongly recommended for karri. If material is dried green off the saw, great care must be taken in placing thermometers, and in following the schedule very closely. Automatic control is practically essential for this purpose.

The time required for drying 1-inch karri green off the saw is about five weeks. 4 in. x 1 in. boards for a special product are being seasoned from about 60 per cent. moisture content in much less time than 5 weeks. The kiln used is a progressive one with natural circulation. Factors contributing to the rapid drying time are (*a*) the narrow width of the boards, (*b*) the quality of timber supplied is almost perfect, and (*c*) the product does not demand an exacting final moisture content specification. The schedule used is not known, but the initial humidity is fairly high, and the temperature is not allowed to exceed 140° or 150° F. at any time.

Material partially air-dried to a moisture content of about 30 per cent. should not require more than ten days' kiln-drying. For drying such material, the schedule should be started with the conditions at the change point corresponding to the moisture content of the timber at the time of putting it in the kiln.

At the end of the drying, a final high humidity treatment should be given, using a dry bulb temperature of 150° F. and a wet bulb depression of 6° F., for several hours. If warping is severe, this treatment can be replaced by a steaming treatment of several hours under saturated conditions at 212° F. Somewhat longer treatments than those for jarrah are required.

Stock less than 1 inch in thickness, apart from case stock, should be dried under the same schedule as 1-inch stock, though the time required will be less.

SCHEDULE I.

Schedule for 1-Inch Green Back-sawn Karri.

Change Points.	Dry Bulb Temperature.	Wet Bulb Depression.	Relative Humidity.
	° F.	° F.	%
Initial	104	3	90
35 % moisture content	106	5	84
25 % „ „	108	7	78
20 % „ „	115	12	66
15 % „ „	125	21	49
12 % „ „ (to final)	135	30	37

Thicker Stock.—The thicker the stock the more desirable is preliminary air-drying where this can be carried out without serious checking, and although the following schedules for green stock are given, it is recommended that preliminary air-drying with suitable precautions be adopted, the kiln-drying being commenced at that part of the schedule corresponding to the moisture content of the timber when placed in the kiln.

If kiln-drying green off the saw is adopted, it is recommended that the drying of stock more than 1-inch thick should not be attempted until at least one charge of 1-inch green material has been dried in the kiln to be used, or, in the case of a battery of similar kilns, in one of the kilns to be used.

SCHEDULE III.

Schedule for Green Back-sawn Karri 2 Inches Thick or Thicker

Change Points.	Dry Bulb Temperature.	Wet Bulb Depression.	Relative Humidity.
	° F.	° F.	%
Initial	94	3	89
35 % moisture content	96	5	83
25 % ,, ,, ...	98	6	79
20 % ,, ,, ...	101	9	71
17 % ,, ,, ...	105	12	63
15 % ,, ,, ...	110	16	55
12 % ,, ,, (to final)	120	24	41

Case Stock.

(1) *Case Ends.*—The results of tests with this class of stock a not as promising as those obtained with jarrah case ends. While seems probable that quarter-sawn karri case ends, ¾-inch thick, co be safely kiln-dried from the green condition in eight or nine da in a commercial kiln, green back-sawn material would take almost tw that time. This difference in drying time, together with the fact th quarter-sawn ends dried under the back-sawn schedule take even long to dry than back-sawn ends, would make it uneconomical to mix ba sawn and quarter-sawn ends for kiln-drying. Kiln-drying from t green condition of sorted back-sawn ends would also be too costly.

Stock less than 1 inch in thickness, apart from case stock, should be dried under the same schedule as 1-inch stock, though the time required will be less.

SCHEDULE I.

Schedule for 1-Inch Green Back-sawn Karri.

Change Points.	Dry Bulb Temperature.	Wet Bulb Depression.	Relative Humidity.
	° F.	° F.	%
Initial	104	3	90
35 % moisture content	106	5	84
25 % ,, ,, ...	108	7	78
20 % ,, ,, ...	115	12	66
15 % ,, ,, ...	125	21	49
12 % ,, ,, (to final)	135	30	37

Thicker Stock.—The thicker the stock the more desirable is preliminary air-drying where this can be carried out without serious checking, and although the following schedules for green stock are given, it is recommended that preliminary air-drying with suitable precautions be adopted, the kiln-drying being commenced at that part of the schedule corresponding to the moisture content of the timber when placed in the kiln.

If kiln-drying green off the saw is adopted, it is recommended that the drying of stock more than 1-inch thick should not be attempted until at least one charge of 1-inch green material has been dried in the kiln to be used, or, in the case of a battery of similar kilns, in one of the kilns to be used.

Schedule II. is for 1½-inch material, mixed-sawn, or back-sawn, and Schedule III. for stock 2 inches or more in thickness. The kiln-drying time will be approximately proportional to the thickness.

A final high humidity treatment similar to that for 1-inch stock should be given, but the length of this treatment will need to be greater, according to the thickness of the stock.

SCHEDULE II.

Schedule for 1½-Inch Green Back-sawn Karri.

Change Points.	Dry Bulb Temperature.	Wet Bulb Depression.	Relative Humidity.
	° F.	° F.	%
Initial	99	3	89
35 % moisture content	101	5	83
25 % ,, ,, ...	103	7	77
20 % ,, ,, ...	106	9	72
17 % ,, ,, ...	110	13	62
15 % ,, ,, ...	115	17	55
12 % ,, ,, (to final)	125	25	42

SCHEDULE III.

SCHEDULE FOR GREEN BACK-SAWN KARRI 2 INCHES THICK OR THICKER.

Change Points.	Dry Bulb Temperature.	Wet Bulb Depression.	Relative Humidity.
	° F.	° F.	%
Initial	94	3	89
35 % moisture content	96	5	83
25 % ,, ...	98	6	79
20 % ,, ...	101	9	71
17 % ,, ...	105	12	63
15 % ,, ...	110	16	55
12 % ,, ,, (to final)	120	24	41

Case Stock.

(1) *Case Ends.*—The results of tests with this class of stock are not as promising as those obtained with jarrah case ends. While it seems probable that quarter-sawn karri case ends, $\frac{5}{8}$-inch thick, could be safely kiln-dried from the green condition in eight or nine days, in a commercial kiln, green back-sawn material would take almost twice that time. This difference in drying time, together with the fact that quarter-sawn ends dried under the back-sawn schedule take even longer to dry than back-sawn ends, would make it uneconomical to mix back-sawn and quarter-sawn ends for kiln-drying. Kiln-drying from the green condition of sorted back-sawn ends would also be too costly.

Material previously air-dried to a moisture content of about 30 per cent. could be kiln-dried at the rate of about two charges per week per kiln, and provided handling costs were not too great, this procedure would be cheaper than kiln-drying from the green condition. By stacking the case-end stock in small unit stacks, it could be transferred from the air-drying yard to the kiln without re-stacking and with small handling costs.

Whether kiln-drying from the green condition or after partial air-drying is adopted, quarter-sawing of case ends is desirable, and it should be just as practicable with karri as with *Eucalyptus regnans*, case ends of which are usually cut on the quarter.

Although quarter-sawing is recommended, tentative schedules for both back-sawn and quarter-sawn stock are given. For partially air-dried material, kiln-drying should be started at the conditions for the change point corresponding to the moisture content of the timber at the time of putting it in the kiln, and the schedule followed through from that point.

The limited effectiveness of a final reconditioning treatment and the danger of resultant checking are such as to make its recommendation for this class of stock questionable.

SCHEDULE IV.

Tentative Schedule for ¾-Inch Green Karri Case Ends.

Change Points.	Quarter-sawn.			Back-sawn.		
	Dry Bulb Temperature.	Wet Bulb Depression.	Relative Humidity.	Dry Bulb Temperature.	Wet Bulb Depression.	Relative Humidity.
	° F.	° F.	%	° F.	° F.	%
Initial	160	6	86	120	3	91
60 % moisture content ..	160	11	75	120	5	85
40 % ,, ,, ..	170	20	60	130	9	76
30 % ,, ,, ..	170	43	30	140	17	60
20 % ,, ,, (to final)	180	45	30	150	31	39

(2) *Case Sides, Tops, and Bottoms.*—As with case ends, kiln-drying from the green condition of ¾-inch back-sawn case sides, tops, and bottoms does not seem to be a commercial proposition, such mild conditions being necessary that the drying time would probably exceed one week. Air-drying to a moisture content of about 30 per cent. would reduce the kiln-drying time for back-sawn stock to about 24 hours, and this procedure would be commercially practicable provided adequate and cheap handling arrangements were made, and provided cupping and twisting did not result in too much degrade. The spacing of strips at close intervals (less than 18 inches apart) would be necessary to prevent severe warping, which apparently cannot be removed by a final steaming treatment. No reasonable schedule can be suggested for green back-sawn material, but a tentative schedule for partially air-dried material is given.

SCHEDULE V.

Tentative Schedule for Partially Air-dried Back-sawn Karri Case Sides, Tops, and Bottoms.

Change Points.	Dry Bulb Temperature.	Wet Bulb Depression.	Relative Humidity.
	° F.	° F.	%
Initial (30 % moisture content)	110	19	48
20 % moisture content (to final)	120	27	36

Quarter-sawn material can be dried from the green state under comparatively severe conditions, the probable drying time in a commercial kiln being two to three days. This should be commercially practicable, but, if not, the kiln time could be reduced to less than 24 hours by previously air-drying the stock to a moisture content of about 30 per cent. To make this practicable, a cheap method of handling, such as that suggested for case ends, would be necessary.

If practicable, quarter-sawing is recommended, and for quarter-sawn material, either green or partially air-dried, the following constant conditions schedule is tentatively suggested:—

Dry bulb temperature	..	..	180° F.
Wet bulb depression	..	..	45° F.
Relative humidity	..	..	30 per cent.

Apparently no useful purpose is served by a final reconditioning treatment.

Eucalyptus gigantea—Red Ash or Woolly Butt (Vic.), Alpine Ash (N.S.W.), White Top (Tas.).

General Notes.

Kiln-drying schedules for this timber have not been determined experimentally, but its behaviour has been observed during air-drying and during the combined air-drying and kiln-drying of a commercial charge, the kiln schedule used in the latter case being the same as that used for *Eucalyptus regnans* at the same plant. Further, it is known to be dried mixed indiscriminately with *E. regnans*, at another plant.

Its behaviour during drying is much the same as that of *E. regnans*, though possibly it might take slightly longer to dry, under the same schedule. It is generally subject to collapse, but recovery under a reconditioning treatment is usually good.

Suggested Schedules.

In the absence of specific schedules those recommended for *E. regnans* are suggested, and the same recommendations regarding sawing and partial air-drying are made. Care should be taken with dense back-sawn material.

Eucalyptus gomphocephala—Tuart (W.A.).

General Notes.

Information regarding the drying of this timber is included by courtesy of the Forests Department of Western Australia, whose tests in a semi-commercial kiln constitute the only investigations made to date. Up to the present, air-drying only has been practised commercially.

Warping, Checking, and Collapse.—Warping is not a serious form of degrade in tuart, and although it has a greater tendency to check than has jarrah, it is not as subject to this fault as is karri. The rate of moisture transfusion through the timber is lower than in jarrah, and periodical steaming treatments throughout the early parts of the run, using saturated conditions at a temperature about 10° higher than the drying temperature, would be beneficial in kiln-drying from the green condition. Collapse has not been observed.

Shrinkage.—No shrinkage figures are available.

Suggested Schedules.

The schedules suggested have been worked out largely by deduction, as comparatively little work has been done on the kiln-drying of the species. Although schedules for drying green material are suggested, there is no doubt that in all cases partial air-drying followed by kiln-drying would be preferable to kiln-drying from the green condition.

For such procedure the kiln-drying should commence at the conditions in the relevant schedule corresponding to the moisture content of the timber at the time it is placed in the kiln.

A final high humidity treatment at a dry bulb temperature of 150° F. and a wet bulb depression of 6° F. is recommended, the length of the treatment necessary depending on the thickness of the material.

One-inch Stock.—The following schedule is suggested tentatively for back-sawn or mixed-sawn stock.

SCHEDULE I.

TENTATIVE SCHEDULE FOR 1-INCH GREEN BACK-SAWN TUART.

Change Points.	Dry Bulb Temperature.	Wet Bulb Depression.	Relative Humidity.
	° F.	° F.	%
Initial	105	4	87
40 % moisture content	107	6	81
30 % ,, ,, ...	109	7	78
25 % ,, ,, ...	111	9	73
20 % ,, ,, ...	114	12	66
17 % ,, ,, ...	118	15	59
14 % ,, ,, ...	124	20	50
12 % ,, ,, (to final)	131	26	42

Thicker Stock.—The following schedules are suggested tentatively for stock greater than 1 inch in thickness:—

$1\frac{1}{2}$-*inch Stock.*—Karri Schedule No. 1.

2-inch Stock.—Karri Schedule No. II.

Stock more than 2 inches thick.—Karri Schedule No. III.

Eucalyptus marginata—Jarrah (W.A.).

General Notes.

The schedules suggested for this timber, apart from those for case stock, are included by courtesy of the Western Australian Forests Department, and are the result of considerable work in semi-commercial and commercial kilns in that State. The case stock schedules are suggested as a result of laboratory kiln investigations only, and have not been tried out in commercial kilns.

Warping.—This is the principal cause of degrade in the kiln-drying of jarrah, in which sloping grain is common. Attempts to remove warping by a final steaming treatment have not been very successful, but the best results will be obtained if the steaming is carried out after the timber reaches the final moisture content required. A short re-drying period will then be necessary, either in the kiln or, during warm dry weather, in the open.

Checking.—With narrow boards such as flooring, checking is not serious in air- or kiln-drying, but with wide and thick back-cut stock due care must be exercised. Isolated cases of checking parallel to the growth rings have been observed.

Collapse.—Very little collapse occurs, except when drying case stock under high temperature schedules. Even then it is not very severe, but neither is it easily removed by a final reconditioning treatment.

Shrinkage.—No shrinkage figures are available except for thin case material, in which a tangential shrinkage of up to 10 per cent. and a radial shrinkage of up to 5 per cent. have been noted in drying to 15 per cent. moisture content.

Suggested Schedules.

Although schedules are given for kiln-drying green material, partial air-drying prior to kiln-drying is recommended, except perhaps for case material. As far as this stock is concerned, it is possible that combined air- and kiln-drying might be more economical for case ends, provided satisfactory handling facilities are available. Kiln-drying green off the saw may be practicable for case sides, tops, and bottoms.

1-*inch Stock.*—Schedule I. is a conservative schedule, for the rapid seasoning of wide back-sawn boards; narrow back-sawn boards and quarter-sawn boards are not so likely to warp and crack, and for these the temperatures in the schedule may be increased by 10° F. throughout, the relative humidities remaining the same or being slightly lowered. Quarter-sawn material is not considered separately as comparatively little of it is cut. The kiln-drying time required for green material is about three and a half weeks for wide boards, and about three weeks for narrow boards. For material air-dried to a moisture content of about 30 per cent., about eight days are required. With partially air-dried material which includes wide boards, kiln-drying should be commenced at the conditions for the change point corresponding to the air-dried moisture content of the stock, and the schedule followed through from that point. Narrow boards (6 inches wide or less) which have been partially air-dried are more easily dried, and if the moisture content is below 25 per cent. and the moisture distribution is fairly even, a schedule rising to a dry bulb temperature of 160° F. with a wet bulb depression of 36° F. will not be deleterious.

At the end of the drying, a final high humidity treatment should be given using a dry bulb temperature of 150° F. and a wet bulb depression of 6° F. for several hours. If warping is severe, this treatment can be replaced by a steaming treatment for several hours under saturated conditions at 212° F.

Stock less than 1 inch in thickness (apart from case stock) should be dried under the same schedule as 1-inch stock, though the time required will be less.

SCHEDULE I.

Schedule for 1-Inch Green Back-sawn Jarrah, particularly for Wide Boards.

Change Points.	Dry Bulb Temperature.	Wet Bulb Depression.	Relative Humidity.
	° F.	° F.	%
Initial	105	6	80
40 % moisture content	110	8	75
30 % ,, ,, ...	110	10	70
25 % ,, ,, ...	115	12	66
20 % ,, ,, ...	120	16	58
15 % ,, ,, ...	130	25	43
12 % ,, ,, (to final)	140	32	35

Thicker Stock.—The thicker the stock, the more desirable is preliminary air-drying where this can be carried out without surface checking, and although the following schedules for green stock are given, it is recommended that preliminary air-drying with suitable precautions be adopted, the kiln drying being commenced at that part of the schedule corresponding to the moisture content of the timber when placed in the kiln.

Schedule II. is for 1½-inch material, mixed-sawn or back-sawn, and Schedule III. for stock 2 inches or more in thickness. The kiln-drying time will be approximately proportional to the thickness.

A final high humidity treatment similar to that for 1-inch stock should be given, but the length of treatment needs to be greater according to the thickness of the stock.

SCHEDULE II.

Schedule for 1½-Inch Green Back-sawn Jarrah.

Change Points.	Dry Bulb Temperature.	Wet Bulb Depression.	Relative Humidity.
	° F.	° F.	%
Initial	105	5	83
40 % moisture content	110	8	75
30 % ,, ,, ...	110	9	73
25 % ,, ,, ...	115	11	68
20 % ,, ,, ...	120	14	62
15 % ,, ,, ...	130	24	45
12 % ,, ,, (to final)	140	32	35

SCHEDULE III.

Schedule for Green Jarrah, 2 Inches or more in Thickness.

Change Points.	Dry Bulb Temperature.	Wet Bulb Depression.	Relative Humidity.
	° F.	° F.	%
Initial	105	4	87
40 % moisture content	110	7	78
30 % „ „	115	9	74
25 % „ „	120	11	69
20 % „ „	125	14	64
15 % „ „	135	22	50
12 % „ „ (to final)	145	33	35

Case Stock.

(1) *Case Ends.*—The maximum drying rate obtainable without degrade is not as great as that for *Eucalyptus regnans*, and about one week would be necessary for drying ¾-inch case stock green off the saw. Where space is available and handling charges can be kept within reasonable limits, combined air- and kiln-drying might prove to be more economical than kiln-drying green off the saw, the time in the kiln being approximately halved in this way. Although collapse is not as serious in this timber as in *E. regnans*, it is much more difficult to remove, and this, together with the fact that back-sawn stock is likely to check after reconditioning, is a factor in favour of partial air-drying, which results in less severe collapse than when green material is kiln-dried. So far as observations to date show, there is nothing on which to base a recommendation for a final reconditioning treatment, unless it is necessary to remove warping. If such a treatment is not given, a final high humidity treatment, as for 1-inch stock, is recommended.

SCHEDULE IV.

Tentative Schedule for ¾-Inch Green Jarrah Case Ends.

Change Points.	Quarter-sawn.			Back-sawn.		
	Dry Bulb Temperature.	Wet Bulb Depression.	Relative Humidity.	Dry Bulb Temperature.	Wet Bulb Depression.	Relative Humidity.
	° F.	° F.	%	° F.	° F.	%
Initial	160	6	86	150	6	85
50 % moisture content ..	160	11	75	150	10	76
40 % „ „ ..	170	17	65	160	16	65
30 % „ „ ..	180	28	50	160	25	50
20 % „ „ (to final)	180	45	30	170	43	30

(2) *Case Sides, Tops, and Bottoms.*—As with case ends, the maximum drying rate obtainable is not as great as for *E. regnans*, but kiln-drying green off the saw should be commercially practicable. The lesser severity of collapse in partially air-dried stock is a factor

in favour of partial air-drying. The kiln-drying time necessary for ⅜-inch green stock would be about three days. There is some difference in the drying rate of back-sawn and quarter-sawn material, but not sufficient to justify sorting. Warping can be reduced by weighting the stacks, but, if serious, can be overcome to some extent by a final steaming treatment under saturated conditions at 212° F. for about for to five hours.

The following alternative schedules are recommended tentatively. In both of these, the conditions are to be kept constant throughout the run. Schedule VB is intended primarily for kilns in which a temperature of 180° F. cannot be maintained.

SCHEDULE V.

TENTATIVE SCHEDULES (ALTERNATIVE) FOR ⅜-INCH GREEN MIXED SAWN JARRAH CASE SIDES, TOPS, AND BOTTOMS.

VA.			VB. (alternative).		
Dry Bulb Temperature.	Wet Bulb Depression.	Relative Humidity.	Dry Bulb Temperature.	Wet Bulb Depression.	Relative Humidity.
° F.	° F.	%	° F.	° F.	%
180	36	40	160	50	21

Eucalyptus obliqua—Messmate (Vic. and N.S.W.), Brown Top Stringybark (Tas.).

General Notes.

Systematic investigation of the drying characteristics of this species has been limited, but has been supplemented by fairly wide general observations. The actual systematic work has been confined to one semi-commercial kiln charge of green mixed-sawn 1¼-inch stock of Victorian origin, a number of laboratory kiln runs with ¾-inch green quarter-sawn Tasmanian weatherboard stock, and one commercial kiln charge of ⅞-inch full green quarter-sawn Tasmanian stock.

Warping, Checking, and Collapse.—Although the density of this timber is, on the whole, greater than that of *Eucalyptus regnans*, the drying characteristics of the two species are not widely different. The rate of drying of *Eucalyptus obliqua*, however, is somewhat slower than that of either *E. regnans* or *E. gigantea*, and the most refractory *E. obliqua* stock is somewhat more difficult to dry without degrade than the most refractory *E. regnans*. Collapse occurs commonly, though it is not usually as severe as in *E. regnans*. Recovery under a reconditioning treatment is usually good, except where excessive collapse has occurred owing to the use of high temperatures in the early stages of kiln-drying green stock. As with *E. regnans*, warping is usually confined to boards cut in close proximity to branches, and in such cases is not readily removed.

Shrinkage.—From the limited figures available, the shrinkage to be expected seems to be much the same as that for *E. regnans*.

Suggested Schedules.

The information available to date indicates that it is safe to dry the lighter grades of this timber under the schedules recommended for *E. regnans,* though a slightly longer drying time will usually be required. If a parcel of dense stock is being dried under one of these schedules, a close watch should be kept for the first signs of checking, and the drying conditions made less severe if these appear. Quarter-sawing and partial air-drying prior to kiln-drying are recommended.

Eucalyptus regnans—Mountain Ash (Vic.), Swamp or Stringy Gum (Tas.).

General Notes.

The observations and recommendations made with regard to this timber are the result of a considerable amount of work in small experimental kilns, in a semi-commercial kiln, and at commercial plants in various parts of Victoria.

Warping.—On the whole, *Eucalyptus regnans* has little tendency to warp due to sloping grain, except in stock cut from top logs, in which portions in proximity to branches are affected. In such cases, the warping which occurs apparently cannot be completely and permanently removed; but as it is usually confined to a few feet in length it can be docked out without great loss, if sufficiently serious to warrant such a step. A more common form of warping is spring, which is prevalent in the timber from some localities, but almost absent in other cases. Spring, fortunately, can be reduced to a large extent by the final steaming treatment recommended for overcoming collapse in this timber. Where the proportion of material developing this form of warping is great, it may pay to stack the boards on edge, at least while being reconditioned, as this method of stacking helps in the straightening of the boards.

Checking.—Back-sawn material, even in narrow widths, has a strong tendency to develop surface checks during the early stages of drying, except in stock ⅜ inch or less in thickness. It requires great care to prevent this checking, either in air-drying or in kiln-drying green off the saw.

Quarter-sawn material sometimes has a tendency to check on the edges, but it is a simple matter to regulate the drying conditions to prevent this, either in air-drying or in kiln-drying. On a few isolated occasions, a considerable quantity of quarter-sawn material has been badly degraded by through checks along the growth rings, but it seems probable that, although these occurred during drying, the initial cause was a weakening due to some undetected factor such as wind movement in the standing tree, or stresses set up in falling.

Both back-sawn and quarter-sawn material have some tendency to develop internal checks, which are usually small, sometimes fairly numerous, and generally most severe in badly collapsed stock. These internal checks do not usually cause serious degrade unless the drying conditions have been unduly severe.

Collapse.—Collapse occurs very commonly in this species. In full quarter-sawn boards, it sometimes produces a more or less regularly corrugated surface, as illustrated in Fig. 1. More commonly, it takes the form of an irregular sinking of the surfaces, except at the edges, as illustrated in Fig. 2. In back-sawn material, severe collapse frequently occurs without being noticeable.

Because of the commonness of collapse, it was the custom, for many years, to cut stock from this species very full in size to allow for the excessive shrinkage. Fortunately, however, the now widely adopted reconditioning treatment, which was first discovered in connexion with this species, makes it unnecessary, in sawing green stock, to allow for more than normal shrinkage.

Examples of recovery obtained by the reconditioning of collapsed timber are illustrated in Fig. 3.

Shrinkage.—The shrinkage to be expected in material in which, after reconditioning, recovery from collapse is complete or almost complete, is as follows, the figures given relating to stock dried to a moisture content of 12 per cent.:—

Tangential shrinkage	..	7–10 per cent.
Radial	..	4–5 per cent.

Suggested Schedules.

Although a schedule for drying 1-inch material green off the saw is included here, the practice of partially air-drying prior to kiln-drying is strongly advised for this species, for all stock other than thin material, such as case stock. The schedules for green material are included simply for use when sudden demands make kiln-drying from the green condition necessary. Further, although a schedule for 1-inch back-sawn material is given, the advantages of quarter-sawing timber of this species are stressed, except for thin case material. There are certain uses for which the back-sawn grain is desirable, and in such cases the schedules given may be used with safety, providing every care is exercised in kiln operation. By quarter-sawing wherever possible, the likelihood of loss from degrade and the cost of drying are reduced considerably.

No schedules have been evolved for stock more than 1 inch in thickness, but provided it is air-dried to a moisture content of about 30 per cent. before placing in the kiln, stock up to 2 inches thick can be dried under the schedules given for 1-inch material, a greater time, of course, being necessary.

In all cases, a reconditioning treatment is recommended, on the lines set out in the supplementary notes.

1-*inch Quarter-sawn Stock.*—For quarter-sawn material green off the saw, the following schedule is suggested, it being a slight modification of one which has proved satisfactory in commercial practice. The drying time necessary is about eleven to fourteen days in an efficient kiln. It has been shown definitely that the use of higher temperatures in the early stages is inadvisable, in that very severe collapse, which it is difficult, if not impracticable, to overcome, frequently results. Further, the use of higher temperatures tends to increase the amount of internal and edge checking.

The common practice of using temperatures of up to 200° F., with very low humidities, towards the end of a run, is neither necessary nor desirable, although the timber might not be visibly degraded thereby.

SCHEDULE FOR 1-INCH GREEN QUARTER-SAWN EUCALYPTUS REGNANS.

Change Points.	Dry Bulb Temperature.	Wet Bulb Depression.	Relative Humidity.
	° F.	° F.	%
Initial	120	10	72
40 % moisture content	130	15	62
30 % ,, ,, ...	140	20	54
20 % ,, ,, (to final)	160	30	43

For partially air-dried stock, the schedule should be started at the conditions for the change point corresponding to the moisture content of the timber at the time of putting it in the kiln. For example, if the timber is air-dried to a moisture content of about 30 per cent., the initial kiln conditions will be a dry bulb temperature of 140° F. with a wet bulb depression of 20° F. When the timber reaches a moisture content of about 20 per cent., the conditions will be changed accordingly. In an efficient kiln, timber air-dried to a moisture content of 30 per cent. should reach a moisture content of 12 per cent. in about five days, if this procedure is followed.

1-*inch Back-sawn Stock.*—The tendency of back-sawn stock of this species to develop surface checks during the early stages of drying necessitates considerable care and close control of kiln conditions until the moisture content is reduced to about 35 per cent. Owing to the predominance of the practice of quarter-sawing 1-inch stock, little attention has been given recently to the development of schedules for back-sawn material, the schedule suggested here being based largely on the results of two semi-commercial kiln runs put through some years ago. The time required for drying in a commercial kiln would be between three and four weeks.

SCHEDULE FOR 1-INCH GREEN BACK-SAWN EUCALYPTUS REGNANS.

Change Points.	Dry Bulb Temperature.	Wet Bulb Depression.	Relative Humidity.
	° F.	° F.	%
Initial	110	5	84
40 % moisture content	120	7	80
30 % ,, ,, ...	120	10	72
25 % ,, ,, ...	130	15	62
20 % ,, ,, ...	140	20	54
15 % ,, ,, (to final)	160	30	43

Back-sawn material which has been air-dried to a moisture content of 30 per cent. or less can be kiln-dried under the conditions suggested for quarter-sawn partially air-dried stock. It will sometimes be

found that surface checks appear soon after kiln-drying of partially air-dried stock is started, but experience has shown that this is really due to the opening of checks formed during air-drying though such checks may be invisible when the material is placed in the kiln. Such checks may not become apparent during kiln drying unless a high humidity or steaming treatment is given. To eliminate surface checking during air-drying, the stock must be stripped with thin strips (not more than ½ inch thick) and protected from the weather.

Case Stock.—Mixed back-sawn and quarter-sawn material about ⅜ inch thick for case sides, tops and bottoms, can be rapidly kiln-dried green off the saw, using a temperature of 180 F. with a wet bulb depression of 45° F. from the outset. The time required in an efficient commercial kiln is about 30 to 36 hours.

Material for case ends, which is about ¾ inch thick, must be quarter-sawn if it is to be dried rapidly, without degrade, from the green condition. A temperature of 180° F. with a wet bulb depression of 28° F. should be held until the moisture content is reduced to about 30 per cent., after which the wet bulb depression may be increased to 45° F., the temperature being left at 180° F. (This schedule is too severe for long lengths of ¾-inch stock intended for weatherboards, which should be dried under a schedule approximating to that for 1-inch stock).

In the rapid drying of both case sides and case ends, the pieces towards the top of the stack may cup badly, but they will straighten during the reconditioning treatment.

Although case stock of this species is being kiln-dried green off the saw with considerable success, it seems likely that partial air-drying is preferable, provided handling costs can be kept sufficiently low. The reason for this is that collapse is much more severe in material dried from the green condition under high temperatures, and satisfactory reconditioning of such stock is sometimes difficult to attain.

Eucalyptus rostrata—River Red Gum (Vic., N.S.W., S.A.).

General Notes.

With the possible exception of isolated charges, kiln-drying of this timber has not been attempted on a commercial scale, the reason being that comparatively little material is sawn for purposes where kiln-seasoning is necessary. Observations have been limited to a few laboratory kiln runs carried out to investigate the desirability of kiln-drying flooring stock, of which a small quantity is sawn.

Warping.—In general, this timber has a strong tendency to warp, twisting due to sloping grain and cupping of back-sawn boards being the principal forms of distortion. Close spacing of strips is recommended as a means of reducing such distortion, and a final steaming treatment will remove it to a large extent.

Checking.—Observations during air-drying have been very limited, but in the small quantity of material kiln dried, it was found possible to prevent surface checking, even of full back-sawn boards, by taking reasonable precautions during the early stages of drying. It was found, however, that a very high humidity had to be maintained until the stock reached a moisture content of 40 per cent., a certain change

of conditions that was quite safe when made at a moisture content of 40 per cent. producing severe checking when made at a moisture content of 50 per cent. Some checking is likely to occur during air-drying, but if the stacks are sheltered it should not be severe.

Collapse.—No obvious collapse has been observed in this timber, but that some collapse does occur was indicated in laboratory tests by a permanent increase in dimensions following a steaming treatment given primarily to remove stresses.

Shrinkage.—In the few boards dried in laboratory kiln runs to a moisture content of 12 per cent., the tangential shrinkage, after the final steaming treatment, was 5½ per cent. Prior to the steaming treatment, this shrinkage was 10 per cent. in the case of material kiln-dried from the green condition, and 6½ per cent. in the case of partially air-dried material.

Suggested Schedule.

As the present practice is to saw most flooring stock of this species on the back, the runs made to date have dealt with back-sawn material only. Partial air-drying prior to kiln-drying is recommended both on account of the saving in kiln time and because of the lesser amount of warping and collapse in partially air-dried stock. The schedule suggested below has not been tried in commercial kilns, but gave satisfactory results in small kiln tests. The drying time to be expected in commercial kilns is about 21 days for green 1-inch back-sawn stock and about five to six days for similar stock air-dried to a moisture content of about 30 per cent.

TENTATIVE SCHEDULE FOR 1-INCH GREEN BACK-SAWN EUCALYPTUS ROSTRATA.

Change Points.	Dry Bulb Temperature.	Wet Bulb Depression.	Relative Humidity.
	° F.	° F.	%
Initial	120	4	88
40 % moisture content	130	11	71
30 %	140	17	60
20 % .. .. (to final)	160	30	43

For 1-inch back-sawn stock air-dried to a moisture content of about 30 per cent., kiln-drying should be commenced at the conditions corresponding to the 30 per cent. change point in the above schedule, which should then be followed through.

Whether the stock is kiln-dried green off the saw or partially air-dried prior to being kiln-dried, a final steaming treatment under saturated conditions at a temperature of 212° F. should be given, for the three-fold purpose of removing warping, relieving stresses, and overcoming any collapse that is present. It is recommended that this steaming treatment be given when the stock reaches the required final moisture content. It should then be followed by a short period of re-drying. The duration of treatment in a commercial steaming chamber cannot be forecast, but it would probably need to be at least six hours.

Eucalyptus sieberiana—Silvertop (Vic.), Coastal Ash (N.S.W.), Ironbark (Tas.).

General Notes.

Very little information is available with regard to the drying of this timber, the only systematic work carried out being two semi-commercial kiln runs of green mixed-sawn 1¼-inch stock, representing ten trees from one Victorian locality. This work, unfortunately, has not been supplemented by general observations, but the following notes will serve as some guide to any one drying the timber before further information is available.

Warping, Checking, and Collapse.—The timber is definitely more difficult to dry without degrade than is *Eucalyptus obliqua,* and the rate of drying under similar conditions is decidedly slower. The main form of degrade to guard against is surface checking. There was no internal checking in the charges observed, and practically no collapse. In one charge, there was a considerable amount of warping, the removal of which by steaming was not investigated.

Shrinkage.—The maximum shrinkage to be expected, in drying to a moisture content of 12 per cent., is about 12 per cent. tangential and about 6 per cent. radial.

Suggested Schedules.

From the information available, it is impossible to recommend any schedule for green stock. Of the two charges that have been observed, the schedule for the first was too severe, for the back-sawn material at all events, while the second was quite satisfactory in so far as degrade was concerned. The drying time in both runs, however, was much too long to be commercially practicable. It seems unlikely that any economical schedule for green stock will be possible, and partial air-drying prior to reconditioning is therefore recommended.

Owing to the tendency of this timber to develop surface checks during the early stages of drying, quarter-sawing is also recommended.

Even for partially air-dried stock it is difficult, at this stage, to suggest a safe schedule that will give a satisfactory rate of drying, and the following suggestions must not be regarded as final. They are not likely to lead to degrade of stock, but the drying time might be unduly great. Stock 1 inch thick air-dried to a moisture content of 30 per cent., can, if quarter-sawn, be dried under the same schedule as partially air-dried *E. regnans.* It is doubtful, however, if partially air-dried back-sawn stock could be dried safely under this schedule, and for such material it is suggested that the 1-inch back-sawn *E. regnans* schedule be followed through from the 30 per cent. change point.

Eucryphia billardieri—Tasmanian Leatherwood.

General Notes.

Information on the drying of this timber is limited to general observations made from time to time, and to one laboratory kiln investigation of the combined air- and kiln-drying of a charge of 1-inch quarter-sawn stock. As the timber seems to be particularly

easy to dry without degrade, however, such observations as have been made are recorded here as a guide to those wishing to dry it before further information is obtained.

Warping.—Very little warping, and none of a serious nature, has been observed.

Checking.—Neither in the air-drying of squares up to 3 inches x 3 inches nor in the kiln-drying, under a comparatively severe schedule, of partially air-dried 1-inch quarter-sawn stock, has any serious checking been noted.

Collapse.—No apparent collapse has been observed, but the possibility of increasing the dry dimensions by a reconditioning treatment has not been investigated.

Shrinkage.—Radial shrinkage only has been noted, the maximum figures obtained in drying to a moisture content of 12 per cent. being 5 per cent.

Suggested Schedule.

As previously pointed out, kiln-drying observations have been limited to 1-inch partially air-dried quarter-sawn material, and even then to a small quantity of material only. These observations indicate that the schedule suggested for sassafras should be quite safe for such material, and the drying-time in a commercial kiln should be about the same as for sassafras. For the relief of stresses at the end of drying, the same treatment as for sassafras is suggested.

When further work has been done, it will probably be shown that kiln-drying from the green condition can be carried out economically.

Nothofagus cunninghamii—Myrtle or Beech (Tas. and Vic.).

General Notes.

The commercial kiln-drying of this species has been carried out for a number of years, the principal sizes so dried being wide 1-inch boards and "squares" for shoe-heel stock. Both kiln-drying from the green or practically green condition and combined air-drying and kiln-drying are practised. Close observations throughout several commercial kiln-charges of shoe-heel stock showed considerable variations in the drying characteristics of this timber, some material being comparatively easy to dry while other material was extremely refractory. The principal difficulties observed were the removal of "wet spots" (Fig. 4) and the prevention of serious internal checks (Fig. 5). Inquiries showed that these two sources of trouble were common, particularly in the drying of shoe-heel squares.

Laboratory kiln investigations to date have definitely shown that this timber varies so much in its drying characteristics that, considering stock of any particular dimensions, some method of sorting into at least two drying-classes is essential for efficient practice. In other words, for stock of any particular dimensions, it is impossible to arrive at a completely satisfactory schedule for the species as a whole. If a charge of unsorted stock is dried, the easily dried material must be delayed, to ensure freedom from degrade in the more refractory material. While the differences throughout a charge are more pronounced when kiln-drying material green off the saw, they are still

appreciable when kiln-drying partially air-dried stock. Laboratory kiln investigations have been suspended until some practicable method of sorting this timber prior to drying has been developed.

Warping.—The only form of warping that has been observed to occur to any extent is the diamonding of squares, cut with the growth rings running diagonally across the end section. This diamonding can be reduced, but not completely removed, by a final steaming treatment.

Checking.—Surface checking does not usually give serious trouble, even in refractory material, but internal checking is often very serious. Squares which show no checks on the ends or sides may contain large internal checks that make them practically worthless (see Fig. 5). As mentioned above, these internal checks, together with "wet spots," constitute the main problem in the drying of this timber.

Collapse.—Collapse is fairly common, and is frequently associated with the largest internal checks. The reconditioning of collapsed stock has not been studied, but some increase in size has been noted in connexion with final steaming treatments to relieve stresses, and the reconditioning of boards is sometimes practised in commercial plants.

Shrinkage.—Shrinkage measurements have been limited to shoe-heel "squares," and reduction of shrinkage by reconditioning has not been observed. In drying to a moisture content of 12 per cent., the maximum tangential shrinkage noted was 14 per cent., and the maximum radial shrinkage 10 per cent. Both these figures would be reduced to some extent by reconditioning.

Suggested Schedule.

As has been stated above, no schedule will be completely satisfactory for unsorted material of any one size, as it will be either too severe for some of the material or unnecessarily slow for some. In spite of this, unsorted material is dried in commercial kilns, though details of conditions used are not known. The schedule suggested here is based simply on experience in drying mixed shoe-heel "squares" in laboratory kilns, and has not been tried in commercial kilns. It should be safe for all except the most refractory timber, but is unnecessarily slow for much material of this species. It is suggested simply as the best that can be offered until sorting of green material is possible.

Partial air-drying prior to kiln-drying is recommended, at least until sorting of green material can be practised. When a method of sorting is developed, it is not likely that drying green off the saw will be as economical as combined air- and kiln-drying, even for the milder material.

As the schedule suggested has not been tried out in large kilns, it is difficult to estimate the drying time that would be required, but this would probably be between 35 and 40 days for 2½-in. x 2¼-in. stock green off the saw, and about 20 days for similar material air-dried to a moisture content of 30 per cent.

A final steaming treatment to remove collapse may not always be necessary, but a final steaming for about two to four hours under

saturated conditions at 150° F., to relieve stresses, is recommended. In addition, intermediate steaming or high humidity treatments may be beneficial.

TENTATIVE SCHEDULE FOR GREEN MYRTLE SHOE-HEEL STOCK.

Change Points.	Dry Bulb Temperature.	Wet Bulb Depression.	Relative Humidity.
	° F.	° F.	%
Initial	105	4	87
40 % moisture content	120	5	85
30 % ,, ,,	125	7	80
25 % ,, ,,	130	10	73
20 % ,, ,,	135	20	54
15 % ,, ,, (to final)	140	28	41

For similar stock air-dried to a moisture content of 30 per cent., kiln-drying should be commenced at the conditions corresponding to the 30 per cent. change point, and the schedule followed through from that point.

Schedules for stock of other dimensions have not been investigated.

Pinus radiata—Insignis or Monterey Pine.

General Notes.

In addition to laboratory kiln investigations, observations of this timber have been made during drying in commercial kilns in South Australia, and one of the schedules recommended has been tried out successfully in New Zealand with timber grown there. The timber is easy to dry without degrade.

Warping.—The most common form of warping experienced with this timber is twist, due to spiral grain. This is not a serious form of degrade in 1-inch stock except when the drying conditions have been too severe, and even then can be reduced to some extent by a final steaming treatment. Careful stacking with weights on top of the stacks, and adherence to reasonable drying conditions, are recommended for reducing the severity of twist. If severe twist is present when the boards are machined, splitting may occur.

In drying thin case stock, there is not much trouble with warping, provided the stacks are weighted.

Checking.—Provided reasonable precautions are taken, serious checking does not occur, though slight surface checking may occur in back-sawn stock. Checking of, and around, knots will give trouble if the drying conditions are too severe.

Loosening of Knots.—Knots are usually tight, but some trouble may be experienced from loosening where encased knots are present.

Collapse.—Collapse has been observed, but is exceptional.

Shrinkage.—Tangential shrinkage only has been observed, and has been found to vary from 2½ per cent. to 4½ per cent. in drying to a moisture content of 12 per cent.

Suggested Schedules.

While both kiln-drying green off the saw and combined air- and kiln-drying are practised, this timber is one with which the former procedure can often be carried out economically. Where twisting due to spiral grain is severe, however, combined air- and kiln-seasoning may be advantageous.

The schedules suggested below are not being adhered to strictly in Australia, but are suggested as a result of laboratory kiln runs, and at least one of those given for 1-inch stock has been tried out successfully in a commercial kiln in New Zealand

There is a very big variation in the initial moisture content of this timber, according to the proportion of sapwood present, the observed limits of this variation being 50 per cent. and over 200 per cent. If it were practicable to sort into two drying classes, separated on this basis, it would be a great advantage from the seasoning point of view. With unsorted stock, there is a risk of getting an uneven final moisture content, and at the best some of the stock must be held in the kiln for an unnecessarily long time.

Joinery and 1-inch Stock.—For flooring, weatherboard, and similar stock, the first schedule is recommended, but for joinery stock, the second should be used. It is probable, however, that if the timber could be sorted into two moisture content classes, stock with an initial moisture content below, say 100 per cent., could be dried under the first schedule, irrespective of the ultimate use for which it is intended.

A final high humidity treatment of about 2½ hours at a temperature of 150° F. and a wet bulb depression of 6° F. is recommended to relieve stresses in 1-inch stock. A correspondingly longer treatment is necessary for thicker stock.

For 1-inch stock, a drying time of about four to five days should be sufficient in an efficient commercial kiln. Joinery stock would require slightly longer.

SCHEDULE I.

TENTATIVE SCHEDULE FOR GREEN PINUS RADIATA FLOORING, WEATHERBOARD, AND SIMILAR STOCK OF ANY MOISTURE CONTENT, OR FOR JOINERY STOCK WITH AN INITIAL MOISTURE CONTENT BELOW 100 PER CENT.

Change Points.	Dry Bulb Temperature.	Wet Bulb Depression.	Relative Humidity.
	° F.	° F.	%
Initial	180	15	70
50 % moisture content	180	30	47
25 % „ „ (to final)	180	50	26

SCHEDULE II.

SCHEDULE FOR GREEN PINUS RADIATA JOINERY STOCK WITH AN INITIAL MOISTURE CONTENT ABOVE 100 PER CENT.

Change Points.	Dry Bulb Temperature.	Wet Bulb Depression.	Relative Humidity.
	° F.	° F.	%
Initial	160	13	71
35 % moisture content	170	26	51
16 % „ „ (to final)	180	45	30

Case Stock.—For drying thin case sides, a constant schedule is recommended, the conditions suggested being a dry bulb temperature of 200° F. with a wet bulb depression of 45° F. In an efficient commercial kiln, the drying time should not exceed twelve hours.

For drying case ends, the following schedule is suggested. The drying time should not exceed 36 hours:—

TENTATIVE SCHEDULE FOR ¾-INCH GREEN PINUS RADIATA CASE ENDS.

Change Points.	Dry Bulb Temperature.	Wet Bulb Depression.	Relative Humidity.
	° F.	° F.	%
Initial	200	30	51
50 % moisture content (to final)	200	50	30

Salix spp.—Willow.

General Notes.

The drying of cricket bat clefts has become of some importance during the last few years, as a considerable number of bats have been made from Australian-grown willow. It has been held, until recently, that air-drying alone was suitable for drying such stock, but lately there has been a trend towards combined air- and kiln-drying, using low temperature schedules. The timber is by no means difficult to dry, but the requirements of a cricket bat are such that considerable care in drying is necessary. In particular, high temperatures should on no account be used at any stage in the drying of stock for this purpose, and partial air-drying prior to kiln-drying is recommended. Observations on commerical kiln charges of bat clefts have been made, in addition to laboratory kiln runs, and although a final comparison of air-dried and kiln-dried bats has not been made, kiln-drying of partially air-dried clefts, using the schedule suggested below, yields a product which such tests as have been made indicate to be satisfactory.

The other main use of willow is for parts of artificial limbs, the biggest user in this direction being the Commonwealth Repatriation Department. The practice is to dry the willow in the log, a procedure which presents very appreciable difficulties and leads to considerable

waste. Much simpler and quicker drying, without the present large percentage of waste from splitting, would be obtained were the material dried in planks or boards, and fabricated. There is everything to commend this procedure from the drying point of view, and it is difficult to conceive of any objection to it. The strength certainly would not be affected, and at least one man has used a leg with a fabricated thigh part and pronounces it to be as comfortable as one shaped from a solid piece.

Warping.—Material for cricket bat stock is necessarily straight grained, and warping is not a problem in the drying of such material.

Checking.—Unless the ends are dried too quickly, sections up to the size of cricket bat clefts do not check readily. Internal checks have not been observed in cricket bat clefts, and checking of any description does not give trouble provided reasonable precautions are taken. A suitable end coating should be used to prevent end-checking, and in this regard it might be pointed out here that the lime coating which is sometimes used is rarely satisfactory.

Timber dried in the log form frequently splits very badly, and while waste from this cause is not always serious, owing to the log splitting fairly evenly into quarters, such an occurrence is purely a matter of chance, and the usefulness of the resulting quarters is dependent on the size of the log.

Collapse and Shrinkage.—Collapse has not been observed in this timber, and no shrinkage figures are available.

Suggested Schedule.

While it may be possible to kiln-dry cricket bat clefts from the green condition without influencing the quality of the bat, partial air-drying prior to kiln-drying is recommended, until this point has been proved. No attempt to develop a rapid kiln-drying schedule has been made, and it is considered inadvisable to make such an attempt. The following schedule, however, will eliminate much of the unnecessary delay which occurs in the latter stages of air-drying.

TENTATIVE SCHEDULE FOR PARTIALLY AIR-DRIED WILLOW CRICKET BAT STOCK.

Change Points.	Dry Bulb Temperature.	Wet Bulb Depression.	Relative Humidity.
	° F.	° F.	%
Initial (about 30 % moisture content) ..	110	10	70
25 % moisture content (to final)	120	15	60

Tristania conferta—Brush Box (N.S.W. and Q.).

General Notes.

With this timber, the principal seasoning problem is one of drying flooring stock, which is cut from those portions of the log remaining after as big a yield as possible of larger sections, such as paving blocks and bridge decking, has been obtained With this as the basis of

conversion, it follows that much of the flooring stock must be back-sawn. Further, as the object of sawing flooring stock is to increase the recovery from the log, it is not practicable to select straight grained timber only; and the timber is one which contains a great deal of irregular grain, especially in the upper logs.

Observations have been made during the combined air-drying and kiln-drying of two commercial kiln charges of this stock, and during several small experimental kiln runs with green 1-inch stock, most of which was quarter-sawn. In addition, the possibility of removing the warping from air-dried ½-inch paling stock has been investigated. Work in the small experimental kilns was stopped, as the warping problem, which provides the main obstacle in the successful drying of this timber, could not be studied in the short lengths to which such work is limited.

Warping.—Either in air-drying or in kiln-drying from the green condition, a big proportion of this timber must be expected to warp, and while this warping apparently cannot be removed permanently by a final steaming, it can be reduced. The practice of block-stacking the green boards for a period before stripping out is said to reduce the amount of warping considerably, but even then it is frequently necessary to machine the stock twice in order to get straight flooring boards. The placing of spacing strips at close intervals, say 12 inches apart, during the entire seasoning process, and the weighing of the tops of stacks, are suggested as possible means of reducing warping to a minimum without the delay occasioned by a period of block-stacking.

Checking.—Checking of back-sawn boards also gives some trouble, a considerable amount of checking, some of it severe, having occurred in the two commercial charges referred to above, which were stacked for air-drying at the beginning of winter. Presumably, this trouble could be overcome by the use of thinner spacing strips (say ½-inch strips) in air-drying, or by careful kiln control in kiln-drying green off the saw.

Collapse.—In kiln-drying from the green condition at least, sufficient collapse occurs to justify a final reconditioning treatment, in which a fairly good recovery can be expected. This treatment also has the effect of removing some of the warping, relieving the severe case compression stresses that tend to develop during drying, and improving the moisture distribution condition of the stock.

Shrinkage.—No figures are available for tangential shrinkage, and only limited figures for radial shrinkage. So far as they go, these indicate that, in kiln-drying material green off the saw to a moisture content of 12 per cent., an average radial shrinkage (including collapse) of about 8 per cent. is to be expected. The degree by which this shrinkage would be reduced by a reconditioning treatment has not been determined.

Suggested Schedule.

Work on the development of schedules was suspended for the reason already given, but the following schedule was found to be satisfactory for 1-inch quarter-sawn material green off the saw. Using this schedule, the time that would be required in an efficient commercial

kiln would be about three weeks, and it is doubtful if 1-inch quarter-sawn boards could be dried from the green condition in less time than this without severe degrade. The conditions are too severe for green back-sawn material, but 1-inch back-sawn material, air-dried to a moisture content of about 30 per cent., could probably be dried satisfactorily under the latter part of the schedule (i.e., under the conditions shown for moisture contents of from 30 per cent. down). Partial air-drying prior to kiln-drying and a final reconditioning treatment of about six to eight hours' duration are recommended.

TENTATIVE SCHEDULE FOR 1-INCH GREEN QUARTER-SAWN BRUSH BOX.

Change Points.	Dry Bulb Temperature.	Wet Bulb Depression.	Relative Humidity.
	° F.	° F.	%
Initial	120	10	72
50 % moisture content	140	10	75
40 % ,, ,, ...	160	13	71
30 % ,, ,, ...	160	20	58
25 % ,, ,, ...	170	25	52
15 % ,, ,, (to final)	180	38	38

III. SUPPLEMENTARY NOTES.

The following definitions and notes are appended in explanation of certain terms used throughout the text, and for general guidance to kiln-operators in preventing or overcoming the various forms of degrade. Fuller information relative to seasoning practice will be found in the Trade Circulars which are published by the Division from time to time. Of such circulars published to date, a list of those relevant to seasoning is given at the conclusion of these notes.

1. Moisture Content.

Information regarding the moisture contained in wood and methods of determining moisture content will be found in Trade Circulars Nos. 2, 3, 7, and 9. In this regard, it is necessary here to point out only that the amount of moisture contained in wood should always be expressed as a percentage of the oven-dry weight of the wood. Thus, it is possible for a piece of wood to have a moisture content greater than 100 per cent., a condition by no means uncommon in green timber of some species.

The final moisture content to which timber should be dried depends on the use to which it is to be put and on the locality in which it is to be used, and for this reason, schedules included in this Pamphlet do not state a final moisture content. In general, however, a final moisture content of about 12 per cent. is desirable for timber in sheltered or indoor positions in Australia, except in drier inland districts, where a moisture content of about 8 to 10 per cent. is desirable.

Moisture Distribution: Moisture Gradient.

The moisture in wood tends to distribute itself evenly by moving from areas of higher moisture content to areas of lower. Thus, if the moisture content of the surface of a piece of green wood is lowered by evaporating moisture therefrom, a movement of moisture from the still wet interior to the drier surface will result—a fundamental principle in the drying of timber. A difference in moisture content between the inner and outer zones of a piece of timber is referred to as a moisture gradient, and it is on the establishment and maintenance of a suitable moisture gradient that the successful drying of timber depends. The reason for this will be evident after reading the sections on shrinkage, stresses and "set," and checking.

In timber which has been properly dried, the final moisture distribution should be even. That is to say, there should be no moisture gradient, or at most only a very slight one—a difference of up to 2 per cent. between the moisture content of the surface and that of the core of a piece is generally allowable.

One other point to note at this stage is that at a certain temperature the moisture content to which the surface of a piece of wood will come is dependent on the relative humidity of the surrounding air. This provides a simple means of regulating the steepness of the moisture gradient during drying. The term "equilibrium moisture content" is used to denote the moisture content at which wood will remain for an indefinite time when the surrounding air remains at any particular temperature and humidity.

2. Shrinkage.

As wood dries, it shrinks, the degree of shrinkage, for purposes of comparison, being expressed as a percentage of the green dimensions. Thus, if a board measures 10 inches in width when green and 9 inches when dried, the shrinkage, expressed as percentage, is—

$$\frac{10-9}{10} \times 100 = 10 \text{ per cent.}$$

In practically all cases, shrinkage in the length of a board (i.e., longitudinal shrinkage, parallel to the length of the wood fibres) is negligible. Shrinkage in the width and thickness of a board is, however, appreciable, and varies according to the direction of cutting relative to the growth rings. Shrinkage parallel to the growth rings (tangential shrinkage) is usually approximately double that at right angles to the growth rings (radial shrinkage), the reason being explained in Trade Circular No. 3.

In a very thin piece of wood, shrinkage would not commence until the moisture content had been reduced to somewhere between 25 per cent. and 30 per cent., according to the species. This moisture content is known as the "fibre saturation point," and is the point at which the last of the free water has been removed from the cell cavities (see Trade Circular No. 3). In an ordinary board, however, shrinkage can usually be observed almost from the beginning of drying—certainly long before the average moisture content of the board is down to fibre saturation point. The reason for this is clear when it is considered

that the drying of the board is dependent on the setting up of a moisture gradient, the lowest moisture content being at the surface of the board. This means that the surface of the board reaches fibre saturation point and commences to shrink while the cells in the centre still contain most of their original free water. The board can be considered to reach fibre saturation point layer by layer, working from the surface inwards, and as each succeeding layer reaches this point it contributes to the shrinkage of the board as a whole, compressing the inner layers which still contain free water. The actual amount of compression which occurs in the inner layers is increased by the fact that wood above the fibre saturation point, particularly when hot, has plastic tendencies, whereas wood below the fibre saturation point is much stiffer and stronger.

This drying of a board, layer by layer, not only accounts for the occurrence of shrinkage before the average moisture content reaches fibre saturation point, but is responsible for one of the principal forms of drying degrade, namely, checking. The latter point is illustrated by the fact that a very thin piece of wood, in which drying does not proceed layer by layer, but at the same rate throughout the whole thickness of the piece, can be dried at almost any rate without checking occurring. On the other hand, the greater the thickness of the piece being dried, the greater is its tendency to check. The practical significance of this will be realized if the schedule for thin *E. regnans* case stock is compared with that for 1-inch stock of the same species.

Another factor must, however, be considered before entering on a discussion of checking.

3. Stresses and "Set".

In the drying of a very thin piece of wood, the piece would simply shrink, and there would be no consequent trouble. But when a board of appreciable thickness is dried, the problem is much less simple.

In the layer by layer drying of such a board, the first critical stage is reached when the outermost layer dries below fibre saturation point, and begins to shrink. (Under ordinary drying conditions, the extreme surface layer will reach this point in a very short time.) The shrinkage of the outermost layers is resisted by the inner layers, which still contain free moisture and have no natural tendency to shrink at this stage. The immediate result is that the outermost layers, having been prevented from shrinking to their full extent, remain in a state of tension stress and cause compression stresses in the inner layers, which, being wet and plastic, will actually be compressed to some extent.

Now, if a very thin piece of wood is dried and prevented from shrinking, it will be in the same condition as the outermost layers in the board considered above. That is, it will contain tension stresses. If, after drying, the force restraining it from shrinking is removed, it will shrink, but not to the same extent as it would have, had shrinkage been unhampered during drying. That is, it can be said to have developed a tension set. Also, if a piece of green wood is compressed, or if a piece of wood below fibre saturation point absorbs moisture, but is prevented from swelling, it will develop compression set, and such a piece of wood, when re-dried, will have a greater shrinkage than formerly.

These two facts have an important practical significance in the commercial drying of timber. Going back to the early stages of the drying of an ordinary board, it will now be seen that, in addition to tension stresses in the outer layers, tension set is developed, layer by layer, from the surface inwards; the inner layers, in addition to containing compression stresses, develop compression set. At this stage, the outer "case" of the board has been so affected that its total ultimate shrinkage will be less than normal, whereas the inner "core" has been so affected that its ultimate tendency to shrink when dried will be greater than normal. Thus, there will ultimately be a tendency for the core to pull away from the case, and the stresses so set up may, if very severe, rupture the inner portion of the board, causing internal checks.

It is evident, therefore, that the second critical stage in the drying of a board occurs when the core dries below fibre saturation point and tends to shrink. Up to this point, the case has been in tension and has developed tension set, whereas the core has been under compression and has developed some compression set. As soon as the core dries below fibre saturation point, however, the tendency to shrink establishes within it tension stresses in place of the compression stresses, though its state of compression set remains unaltered. At the same time, the pulling in of the core on the case creates compression stresses in the case, in place of tension stresses, although the tension set of the case still remains. This new stress condition will remain and continue to increase in severity until drying of the core ceases.

The actual forms of degrade resulting from the stresses developed during drying are considered below under the headings "checking" and "warping" respectively. Without referring to them specifically, however, it is evident, from the above, that degrade will increase with increase of stresses and of degree of set, and that the severity of these will be dependent on the steepness of the moisture gradient set up during the early stages of drying.

In other words, if the humidity of the air during the early stages of drying is too low, the drying of the case of the board will be too rapid as compared with that of the core (too steep a moisture gradient will be established), severe stresses and a high degree of set will be developed, and degrade will result.

Degrade will also result if the drying temperature used is too high, since timber becomes weaker and more plastic at high temperatures, especially when wet.

It is not practicable to dry timber without developing some stresses and set as described above, but by regulating the drying conditions it is practicable to regulate the severity of the stresses, and so eliminate degrade.

Stresses may be relieved from time to time throughout the drying treatment, as described below under "Prevention of Checking," and a final treatment (either high humidity or steaming under saturated conditions) is usually necessary to free the timber from stresses.

Detection of Stresses.—The standard method of determining the stress condition in a piece of timber is to cut a section similar to a moisture content section and to saw this into prongs, with the saw cuts

parallel to the original wide surface of the piece. This section should be about 1 inch in length in the direction of the grain, and should be cut at least 18 inches from the end of the piece. Each prong should be *approximately* ¼ *inch* thick—four prongs in a piece 1 inch thick.

The behaviour of the prongs should be noted, both at the time of sawing and after standing in a warm room or in some like position, until they come to equilibrium with the atmospheric conditions. The direction in which the prongs turn shows the type of stresses present in the case and core respectively, and the degree of curvature of the prongs, and their relative lengths, indicate the severity of these stresses.

Fig. 6 illustrates the types of prong behaviour obtained at different stages of drying and gives an explanation of each combination of stress conditions. In this figure, to save space, the term "steaming" has been used for high humidity treatments as well as for treatments under saturated conditions. The actual nature of the treatment for each particular case must be taken from the text of these notes. It is important to remember that stages 1 and 2 in this figure will always occur during the drying of timber.

The important thing is to prevent the stresses from becoming too severe, and finally to have the timber as nearly as possible free from stress, as in stage 3A.

Once a satisfactory schedule for a particular size and species is known, it is not necessary to make stress tests during the run—except, perhaps, for comparatively thick material being dried green off the saw —but it is always advisable to make such tests at the conclusion of a run before the timber is machined or put into stock. If stresses are present in the timber in its finished condition, they are likely to lead to serious warping when it is machined.

Irregular results are sometimes obtained when stress tests are made on hot timber. This feature is being investigated, and in the meantime it is recommended that the tests be made on timber which has been allowed to cool.

4. Checking.

Checking is the cracking or separation of the wood longitudinally during drying, as the result of severe stress and "set" conditions as described above. On the whole, checks are considerably shorter than shakes, which are not drying defects.

Because tangential shrinkage is greater than radial shrinkage, and because there are natural lines of weakness in the radial direction along the medullary rays, checks usually run radially through a piece of timber, i.e., at right angles to the growth rings. In some cases, however, checks occur along the junction of the late wood with the early wood (see Trade Circular No. 3), running tangentially through the piece.

Types of Checks.

The following types of checks occur commonly:—

End Checks.—Occur on the ends of the piece, particularly in large sections which sometimes must be end-coated to reduce the rate of end-drying and so prevent this form of degrade.

Internal Checks.—Have their origin in the interior of a piece, but may, if very severe, extend to the surface. They are formed during the latter stages of drying, but are the indirect result of the drying conditions being too severe in the earlier stages (see notes above on stress and "set").

Surface Checks.*—Occur in the surface, normally during the comparatively early stages of drying. Later, the edges of the checks may nip together like the jaws of a pair of pincers, so that the checks are not visible on the surface, though they may be visible when the piece is dressed.

Surface checks which are invisible on the surface at the end of drying will be visible after a final prolonged steaming, such as is given for reconditioning collapsed stock. Further, it is possible to form new checks by such a treatment, owing to the compression set established in the surface layers, which consequently shrink more than normally when re-dried.

Through Checks.—Extend through the piece from one surface to another. When situated at the end of a piece, they are called splits.

Prevention of Checking and Relief of Stresses.

The prevention of checking amounts to the prevention of severe stress conditions during drying. It should be remembered that stresses should be kept within reasonable limits, even with a timber which has very little tendency to check, because a severe stress condition, quite apart from checking, is in itself undesirable.

The occurrence of any form of checking is an indication that the drying conditions have been too severe. The trouble may be surface checks formed during the early stages of drying, or internal checks formed after the core has dried below fibre saturation point; in either case, the actual cause is the use of too severe conditions in the early stages of drying. Surface checks formed after steaming dried timber are the only checks not attributable to the early drying conditions.

To say that the drying conditions have been too severe means that too steep a moisture gradient has been established, and as this is dependent on the wet bulb depression of the drying atmosphere, the control of drying conditions is largely a matter of control of wet bulb depression. The question of temperature must also be considered, since timber is weaker, and therefore will not resist such strong stresses at high temperatures. That is to say, the stresses resulting from the establishment of a given moisture gradient at the beginning of drying of green stock may be quite safe at a certain temperature, but may prove disastrous at a higher one. The actual temperature and the moisture gradient permissible will depend on the species being dried.

The relief of stresses is dependent on the fact that timber becomes somewhat plastic when hot and moist, the method of relief being to subject the timber to a steaming (saturated conditions) or a high humidity treatment. So many factors, of varying relative importance, have to be considered that it is impossible to prescribe any one particular treatment for the relief of stresses in all species under all conditions. It should be the aim of the kiln-operator to

* Surface checks include edge checks, which usually occur in quarter-sawn stock only.

prevent the stress-condition in his timber from becoming serious, rather than to remedy the trouble after it has occurred. It will occur at times, however, and the suggestions offered here are submitted as a guide in such cases.

In kiln-drying from the green condition, the timber should be inspected frequently for surface checks, the presence or absence of which may usually be taken as an indication of the condition of the stock, as regards stresses, in the early part of the run. If the schedule used from the outset is suitable, surface checks will not form. Their occurrence is an indication of too steep a moisture gradient having been established, and in addition to any degrade which might arise as a result of the surface checks themselves developing as drying proceeds, there is also the probability of their being followed by internal checking. The first objective, therefore, is to try to prevent surface checking.

If surface checks do occur, the wet bulb depression should be reduced as soon as they are noticed, and drying continued under the less severe conditions. If the checks formed are at all severe, they may, as drying proceeds, nip together at the edges, like pincers, gradually closing on the surface, but leaving definite openings beneath the surface. This nipping will take place before the core proper reaches fibre saturation point, and is most likely to occur in thick stock. If drying is continued without anything being done to relieve the condition, such checks will extend deep into the piece, and become a serious source of degrade. The only way to prevent this deepening of the checks is to give a short, high temperature steaming treatment as soon as the checks begin to nip. This treatment will develop compression set in the immediate surface layers. Hence, as drying continues the checks will be more pronounced than before on the surface, but the treatment will prevent them from extending too deeply into the timber. A high humidity treatment (conditions not saturated) will not do in place of a steaming treatment for this purpose, but will make the original condition worse, as the surface will be caused to swell without at the same time becoming sufficiently softened to yield to the compression stresses set up, and will therefore tend to force the checks inwards.

It should be noted that the above treatment will relieve the tension set in the immediate surface layers only. The set in the case as a whole (i.e., a zone about ¼ inch thick on the outside of a 1-inch board, for example) can be relieved only after the core moisture content has passed below fibre saturation point.

It has been pointed out that the second critical stage in drying a piece of timber is reached when the core dries below the fibre saturation point, and consequently begins to shrink. It is at this stage that internal checking is likely to begin. Up to this, it is necessary to keep the surface as moist as is compatible with the need for establishing a sufficiently steep moisture gradient to give a reasonable drying rate. Once the core starts to shrink, however, the surest way to prevent internal checking is to keep the moisture gradient as steep as possible by lowering the surface moisture content. On the other hand, as pointed out above, this is the first stage at which the tension set of the case as a whole can be relieved; and such relief depends on some increase in the moisture content of the case. If a steaming treatment (saturated conditions) or a very high humidity treatment be given, a comparatively large increase in moisture content of the case will

occur; severe internal checking may result, particularly in thick stock due to the fact that the tendency of the case to swell will increase the tension stresses in the core. The only safe treatment is a high temperature one at a humidity just high enough to raise the moisture content of the surface of the timber two or three per cent. Even with this treatment, it is best to wait until the core moisture content has reached about 20 per cent., by which time the wood will have gained somewhat in strength and will be better able to resist the stresses set up. In a final stress relief treatment, the core moisture content will have reached about 10 to 12 per cent., so that there will be little danger of causing internal checking in this way.

These points are of great importance, as they affect the initial conditions which can be used safely for partially air-dried stock. Such stock will often have a core moisture content just about fibre saturation point, and, if it has, should on no account be given an initial steaming treatment. For the heating up of the charge, the temperature and wet bulb depression of the initial conditions of the schedule for partially air-dried stock should be aimed at. Contact with the cold timber will, by cooling the air, automatically reduce its wet bulb depression, and this will take the place of a preliminary high humidity treatment.

It should be noted that while a low humidity will not cause internal checking in partially air-dried stock, high temperatures may do so, as the higher the temperature the less is the resistance of the timber to stresses already existing.

The danger of steaming stock with a core moisture content below fibre saturation point has been considered so far only from the point of view of internal checking. Steaming of such stock, however, is likely to lead to serious surface checking in some species, as the surface layers develop a severe compression set during the steaming and consequently tend to shrink excessively when re-dried. Not only is there the likelihood of checks developing, on this account, but in addition, if the treatment is being given for the final relief of stresses the desired result will not be attained, but the case compression stresses will be changed to equally undesirable case tension stresses. Speaking generally, therefore, the final treatment for the relief of case compression should be a high temperature treatment at a humidity corresponding to a moisture content not more than 2 or 3 per cent. higher than that of the surface of the timber. With species not liable to surface check, a steaming treatment can be given with consequent time saving. In the notes on "Collapse," it is shown also that, in certain instances, departure from this general rule is desirable. Some guide to suitable humidities for these final treatments will be obtained from the kiln control table towards the end of this Pamphlet.

5. Warping.

Types of Warping.

A warp is any variation from a true or plane surface, the following types of warping occurring commonly in timber:—

Bow.—A curvature from the plane of the wide face (i.e., flatwise) in the direction of the length only.

Cup.—A simple curvature in the plane of the transverse section.

Spring.—A simple curvature of the edge of a piece of timber, not affecting the face.

Twist (or Wind).—A spiral distortion along the length of a piece of timber.

Spring occurs as soon as a green log is sawn, and also as the result of drying. Other forms of warping, however, occur only after drying has commenced. They may occur in straight grained timber, as a result of uneven drying of different parts of the individual pieces or as a result of bad placement of spacing strips in drying stacks. On the other hand, they may be caused primarily by the direction of grain of the timber, in which case they are due to the difference in relative shrinkage in the longitudinal, radial, and tangential directions. For example, if allowed to shrink freely, a board with spiral grain will develop a twist during drying, and a wide back-sawn board, dried evenly from both wide surfaces, will tend to cup, the side of the board on the outside of the growth rings shrinking more than the other.

When a perfectly flat, dry board is deep sawn, the two halves will sometimes cup badly. This is due to the board not being free from stresses set up during drying, and is an indication of the practical value of the stress tests already described and recommended for use at the conclusion of drying. If the halves cup with the freshly sawn faces concave, the surface compression stresses were not removed from the original board. If the freshly sawn faces become convex, surface tension stresses were present in the original board, due to over-steaming. The same effects may be obtained when a board is dressed more on one side than the other.

Prevention and Removal of Warping.

Warping, apart from spring, will not occur in straight grained timber provided the drying is even and the spacing strips are placed in vertical alignment and at sufficiently frequent intervals along the length of the stack (see Trade Circular No. 1). A further exception to this is cupping, which may occur in wide back-sawn boards near the top of a stack, though it will usually be prevented in other parts of the stack by the weight of timber.

Warping of timber with sloping grain can generally be reduced appreciably by placing spacing strips closer together—say at 12 inch or 15 inch intervals.

In most cases, it is possible to remove warping permanently by steaming the timber at a temperature of about 212° F. for sufficient time to cause it to straighten under the load imposed by the rest of the stack. In some cases of bad warping, it may be necessary to re-stack the timber, with extra spacing strips, to attain the desired result. Even then it is not always possible to overcome the trouble completely (see notes on N.S.W. brush box). In general, the best time to carry out this treatment is when the timber has reached the final moisture content required. If carried out earlier, warping may occur again as the timber dries, the amount of drying being greater than when only moisture picked up during the treatment has to be removed. The steaming should not be longer than is absolutely necessary, owing to the danger of setting up surface tension stresses,

and the timber should be allowed to re-dry in the stack before it is machined or put into stock.

The best results in the removal of spring seem to be obtained when the timber is stacked on edge during the steaming treatment.

Where warping is prevalent in the class of timber being cut, it can often be reduced by the use of the combined air and kiln seasoning system rather than by kiln-drying green from the saw.

6. Collapse.

Collapse is a flattening of the cells during drying, and is sometimes manifested in excessive and uneven shrinkage. It occurs during the early stages of drying, and in this regard differs from normal shrinkage. It is not common to all timbers, but in some timbers was a serious source of waste until a method of overcoming it was discovered. In matched material, collapse is most severe when timber is kiln-dried from the green condition under a high temperature schedule, and least severe when timber is air-dried. It does, however, assume serious proportions in air-drying. It is commonly associated with severe internal checking.

Prevention and Removal of Collapse.

There is no method of preventing collapse from occurring, though it can be reduced by drying at low temperatures. Timbers which are prone to collapse should be partially air-dried before kiln-drying, or kiln-dried under low temperature conditions during the early stages of drying. This, however, is not necessary when drying thin material, such as case stock.

Fortunately, collapse can usually be removed by a simple steaming treatment, given at or near the end of drying. This "reconditioning" treatment* consists of steaming the timber at a temperature of about 212° F. until the collapse disappears. It is usual and desirable to steam in a special chamber rather than in a kiln, partly to reduce deterioration of the kiln and equipment and partly to prevent waste of effective kiln time. The usual time required for 1-inch *Eucalyptus regnans* is about eight hours. The time, however, is dependent on the species, and on the severity of collapse. The timber should be re-dried after the treatment, particularly as the treatment itself sets up severe surface tension stresses, which are caused to move in somewhat from the surface during re-drying, and become of less practical significance. There is always a risk of cupping if reconditioned timber is deep-sawn, but if the treatment is carried out properly, along the lines suggested above, cupping will not usually result from uneven dressing of opposite faces. It is not satisfactory to dry timber well below the final required moisture content, so that after the reconditioning treatment it will be at the correct moisture content. Re-drying is an essential part of the treatment where relative freedom from stress is desired.

The removal of collapse by the reconditioning treatment is permanent. To re-induce the collapse it is necessary to raise the timber again above fibre saturation point. Minor modifications of the present practice may be suggested in the near future, as a result of investigations now being made.

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* Discovered by Grant Bros. of Warburton, Vic.

7. Kiln Schedules.

In working to the kiln schedules given in this Pamphlet, the procedure is to hold the initial conditions until the first change point is reached—in most cases, when the moisture content of the timber is down to 40 per cent.—when the conditions should be changed as indicated, and held at the new values until the next change point is reached, and so on.

In kiln-drying timber from the green condition, intermediate steaming or high humidity treatments might be necessary in some cases, but, as far as possible, the schedules have been fixed to make such treatments unnecessary. If they have to be used, the guiding notes above should be followed.

In kiln-drying stock from the green condition, an initial steaming treatment can be given, if desired, to heat the timber quickly.

Wet Bulb Depression.

Attention is drawn to the use of wet bulb depression figures in these schedules, in place of actual wet bulb readings. The wet bulb depression is simply the number of degrees by which the wet bulb temperature is lower than the dry bulb temperature. The corresponding relative humidity has been given in each case, since the present custom is to regulate schedules largely on the basis of relative humidity and dry bulb temperature; but the wet bulb depressions have been included for a definite purpose.

The wet bulb depression gives a much more direct indication of the severity of drying conditions than does the corresponding relative humidity. Within limits, any particular wet bulb depression corresponds approximately to a certain equilibrium moisture content of timber, *irrespective of the dry bulb temperature.* For example, a wet bulb depression of 10° F. corresponds approximately to an equilibrium moisture content of 12 per cent. whether the dry bulb temperature be 110° F. or 180° F. The corresponding relative humidity at each of these temperatures is 70 per cent. at 110° F. and 79 per cent. at 180° F. Therefore, it is much more difficult to get a mental picture of the severity of conditions at a certain point in a schedule if the schedule is expressed in terms of relative humidity than if it is expressed in terms of wet bulb depression.

Recognition of this fact is due to members of the staff of the Forest Products Laboratory of Madison, U.S.A., from whose publications the following table is taken. The principle of thinking of schedules in terms of wet bulb depression is commended as being of considerable practical value. At the same time, the question of temperature cannot be entirely overlooked, and the temperatures recommended in these schedules should be adhered to approximately, although a slight variation will be of no consequence provided the wet bulb depression remains unaltered.

KILN CONTROL TABLE.

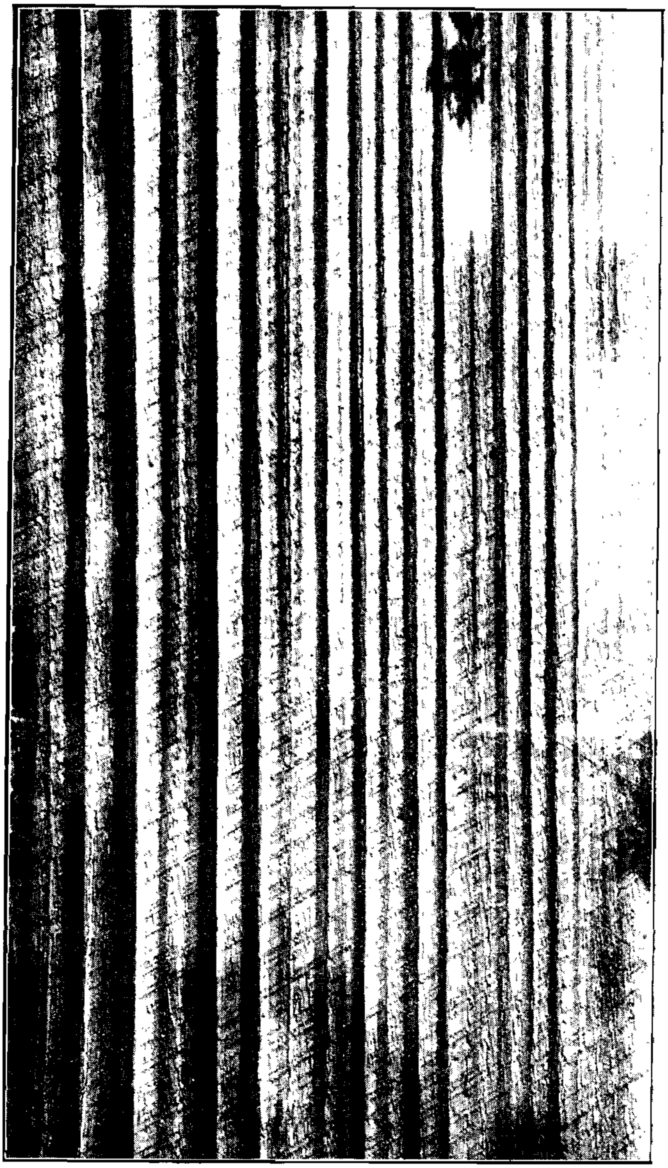
Wet Bulb Depression. °F.	Corresponding Equilibrium Moisture Content. Per cent.
1.5	24
2	22
3	19
4	17
5	15
7	13
9	12
11	11
13	10
15	9
18	8
21	7
25	6
30	5
40	4
50	3

licable to all conditions above 90° F. at saturation and 135° F. er cent. relative humidity.

(After Forest Products Laboratory, Madison, Wisconsin, U.S.A.).

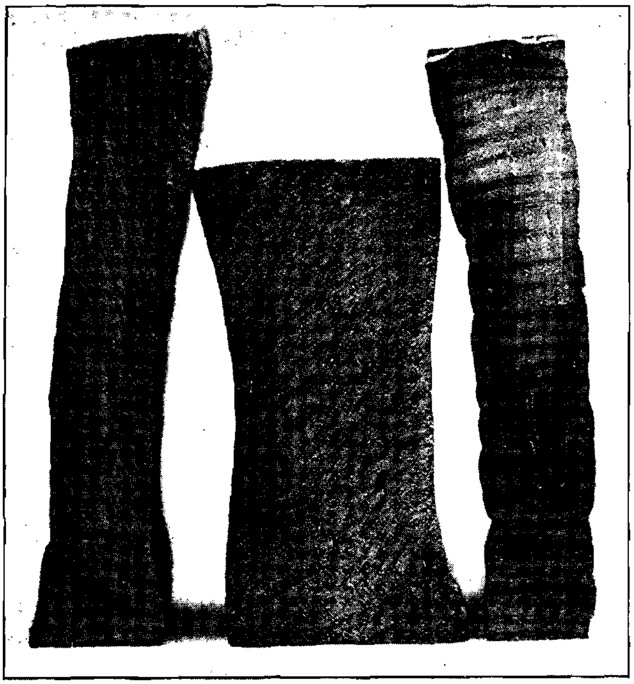
8. Trade Circulars Dealing with Timber Seasoning.

No. 1.—Air Seasoning of Boards.
No. 2.—The Testing of Timber for Moisture Content.
No. 3.—The Growth and Structure of Wood (2nd Edition).
No. 7.—Sample Boards.
No. 9.—Electrical Moisture Meters.
No. 12.—Combined Air and Kiln Seasoning.
No. 16.—Terms used in Seasoning. Part 1. (In the press.)



Block kindly lent by the Forests Commission of Victoria.

FIG. 1. Surface view of collapsed board showing "wash-boarding" or corrugation.



Block kindly lent by the Forests Commission of Victoria.

Fig. 2. End view of collapsed boards showing two major types irregularity caused by collapse.

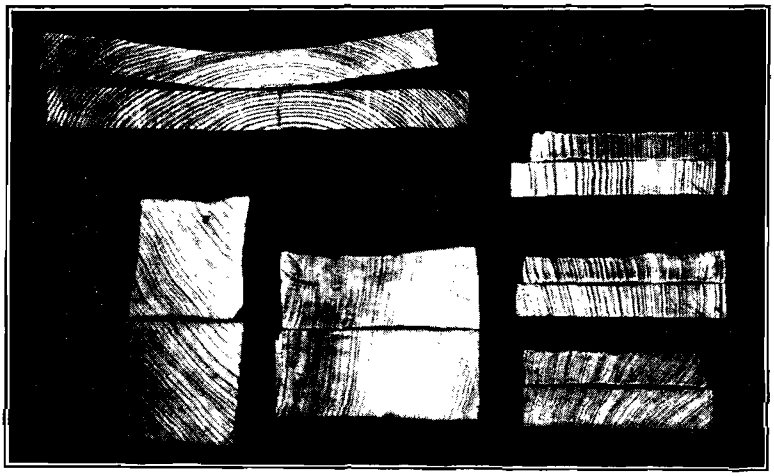


Fig. 3. Collapsed samples paired with matched pieces which have been re-conditioned.

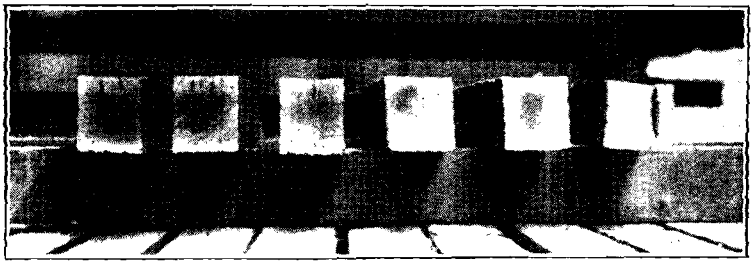


FIG. 4. Wet spots in myrtle squares.

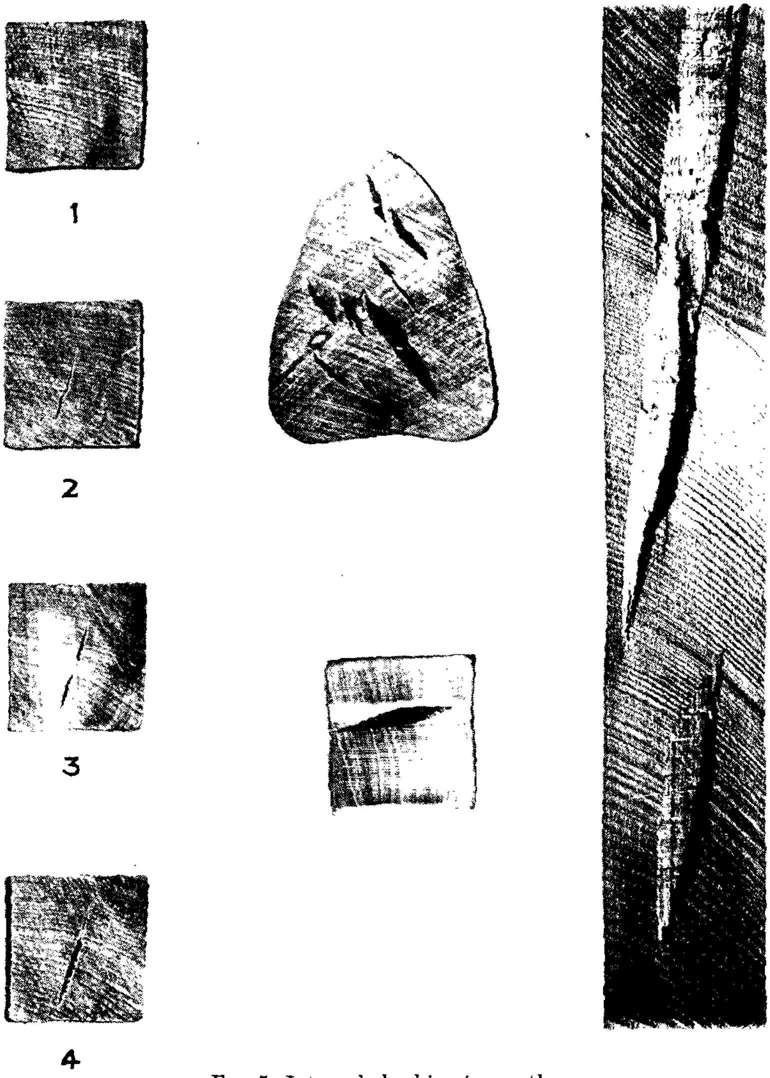


FIG. 5. Internal checking in myrtle.

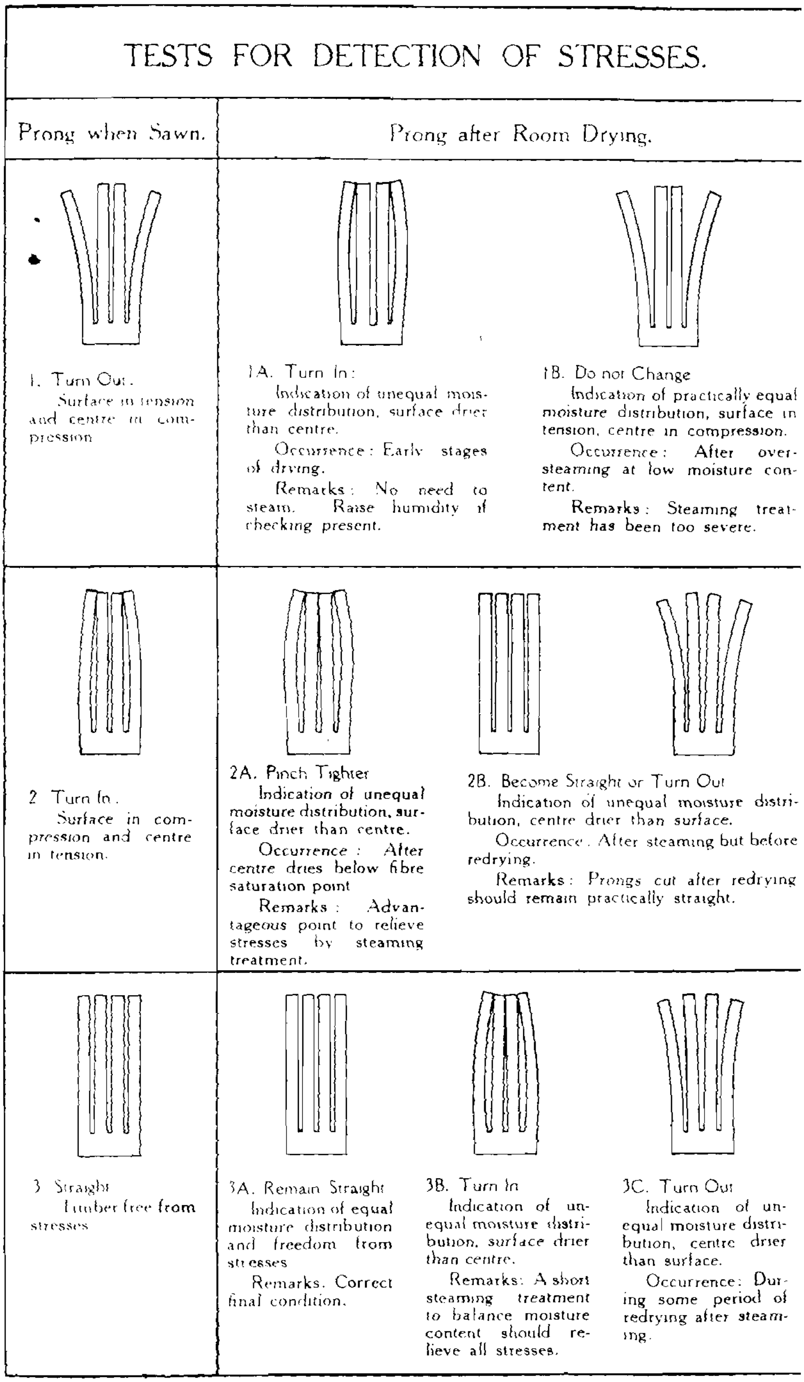


FIG. 6. Tests for detection of stresses.

H. J. Green.